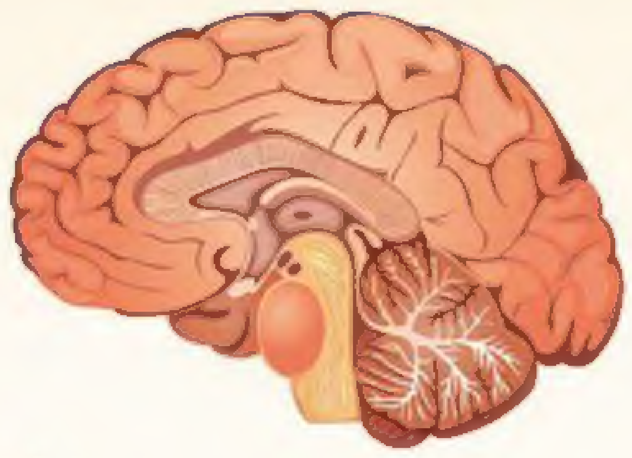
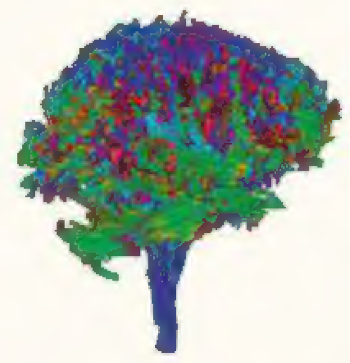
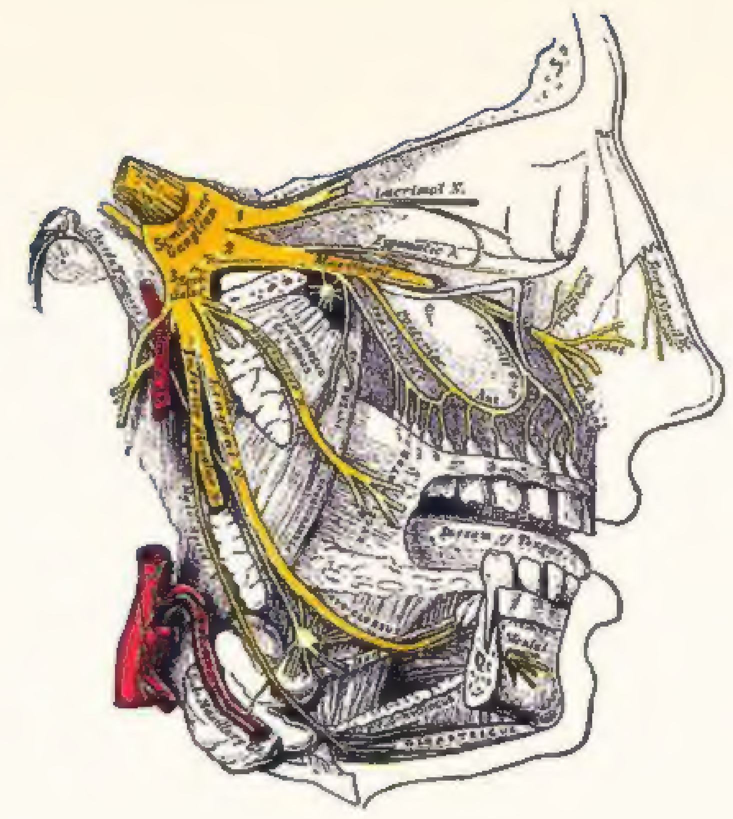
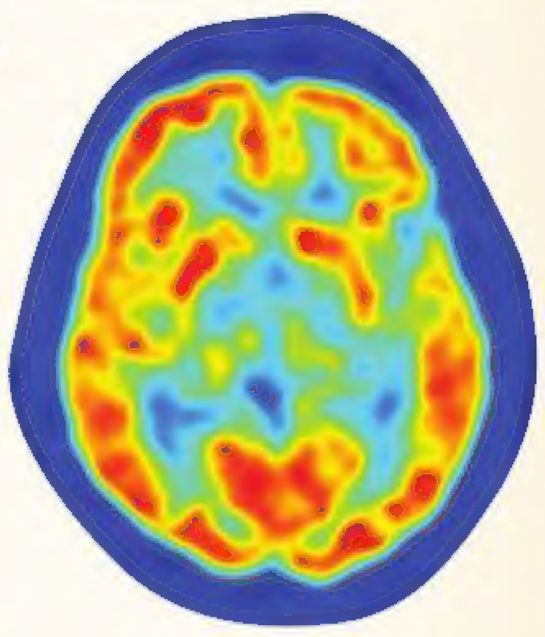
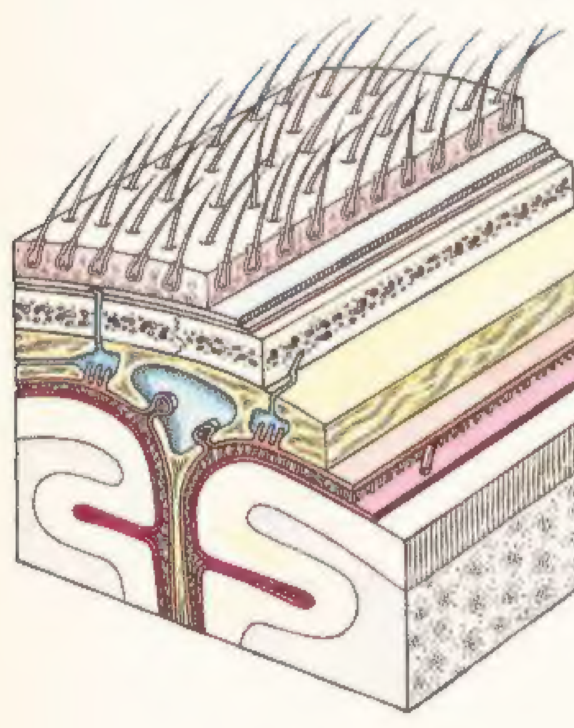
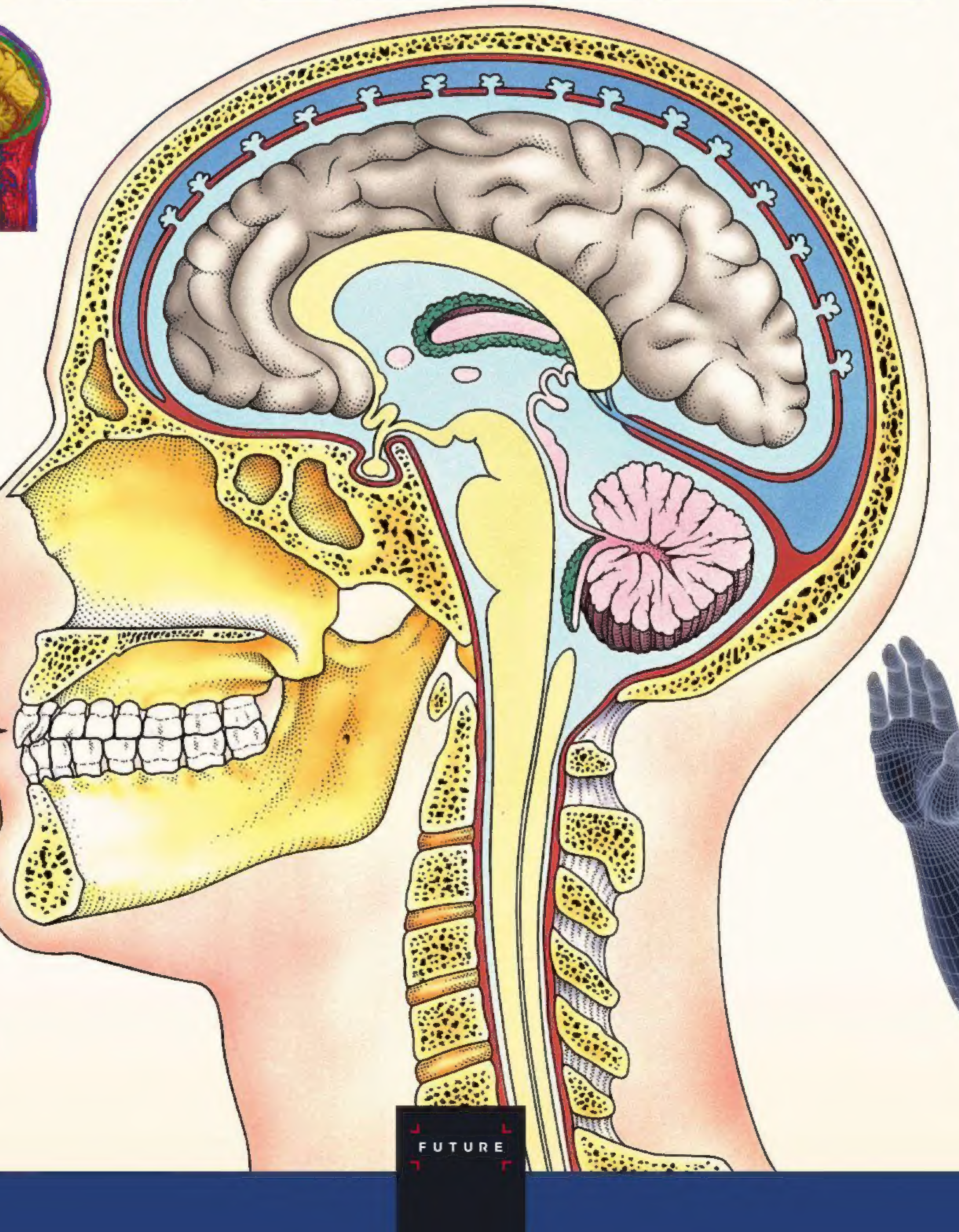
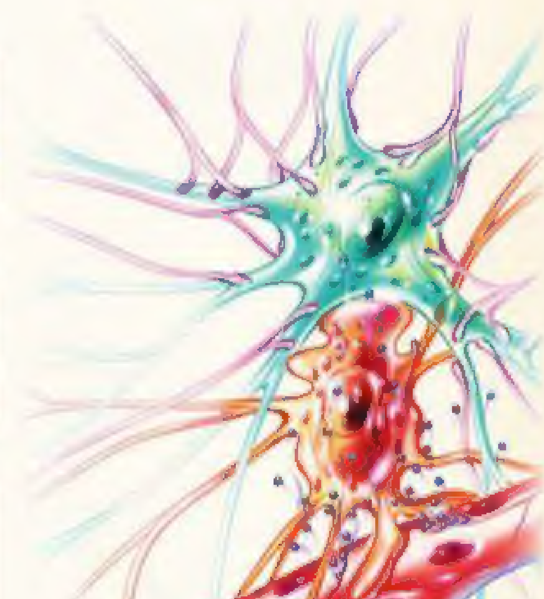
HOW IT WORKS BOOK

THE HUMAN BRAIN



FUTURE

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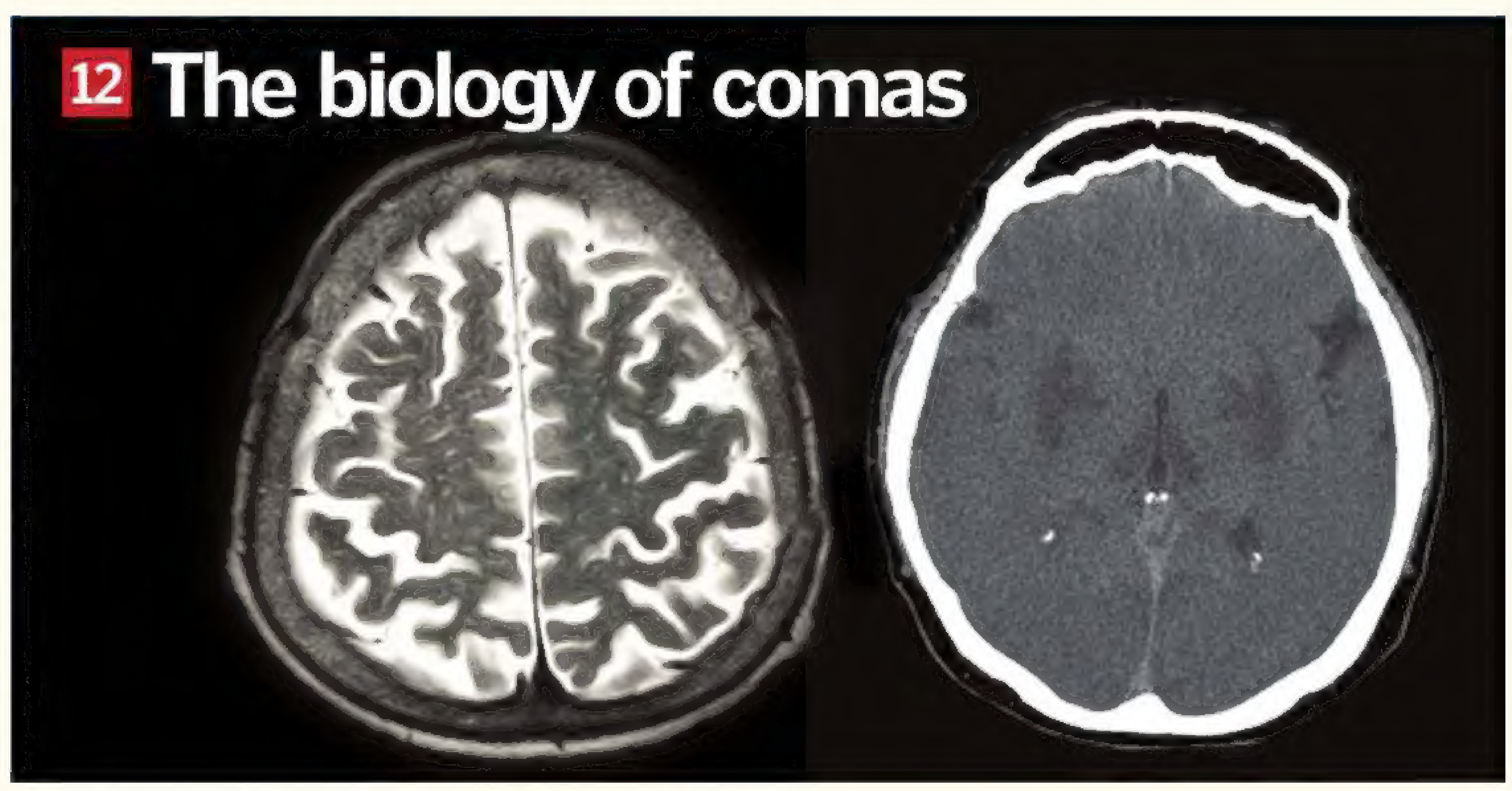
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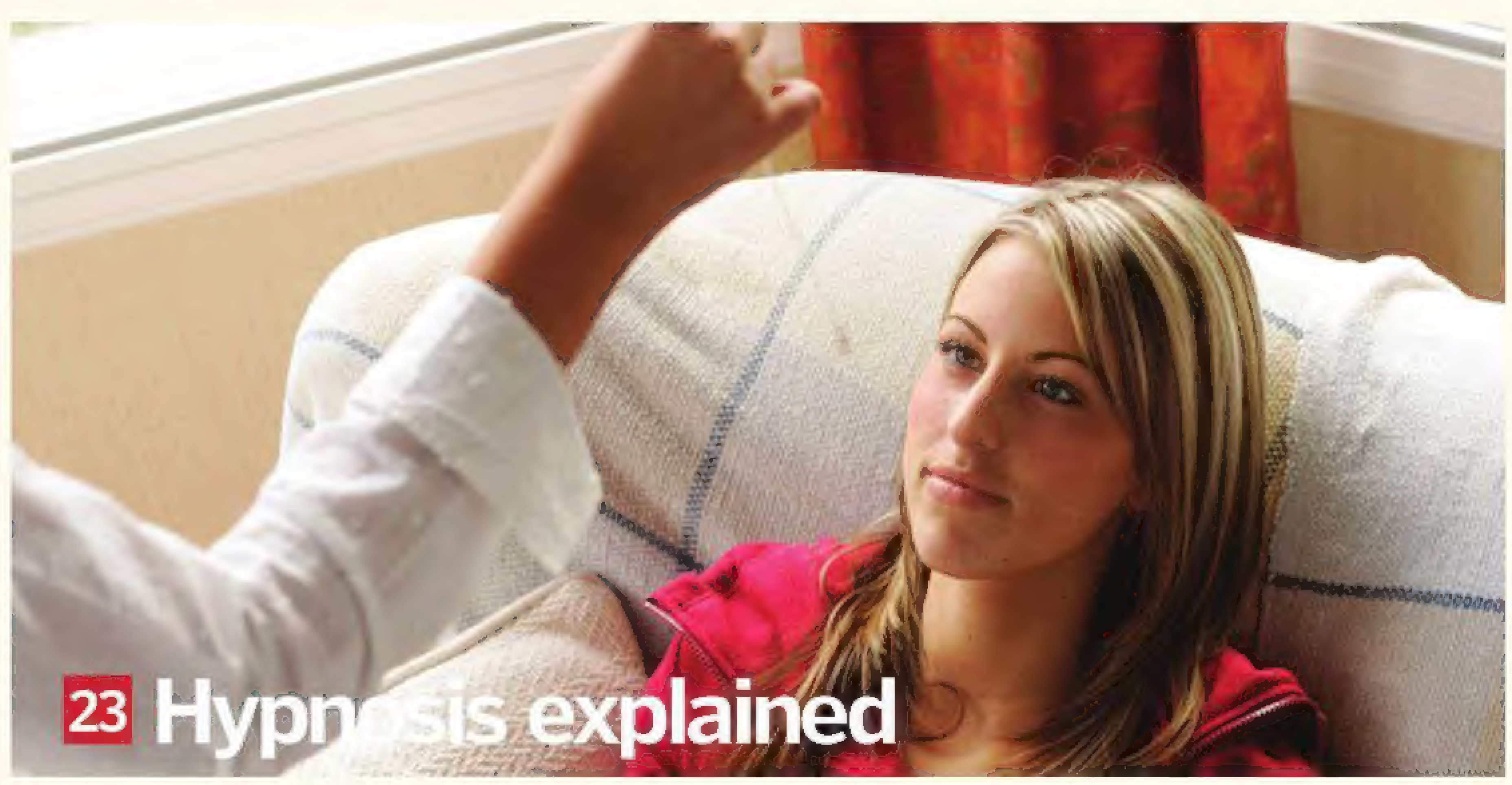
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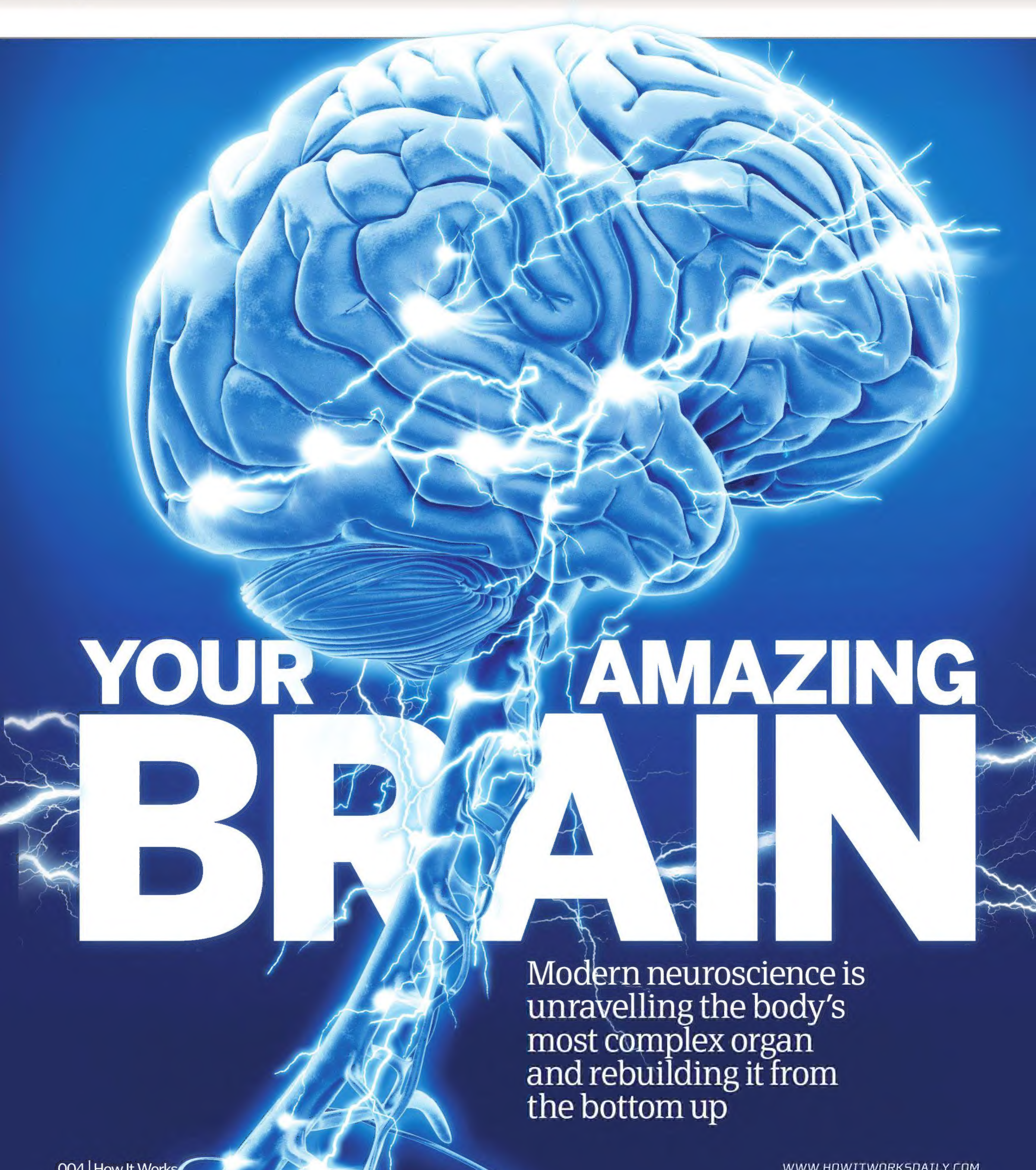
"It weighs little more than a bag of sugar, but packed inside it are 86 billion neurones"



YOUR AMAZING BRAIN

Modern neuroscience is unravelling the body's most complex organ and rebuilding it from the bottom up

5 TOP FACTS
BRAIN CELLS

Neurone
1 When we think of the brain, the first cell that comes to mind is the nerve cell. The average human brain has 86 billion neurones.

Tracking device
2 These cells produce a fatty substance called myelin. This surrounds the axons of neurones in the brain, providing insulation similar to the plastic wire on an electrical cable.

Astrocytes
3 These star-shaped cells provide support to the other cells of the brain, assisting with biochemical processes, guiding growing nerves, directing scarring and repair after injury.

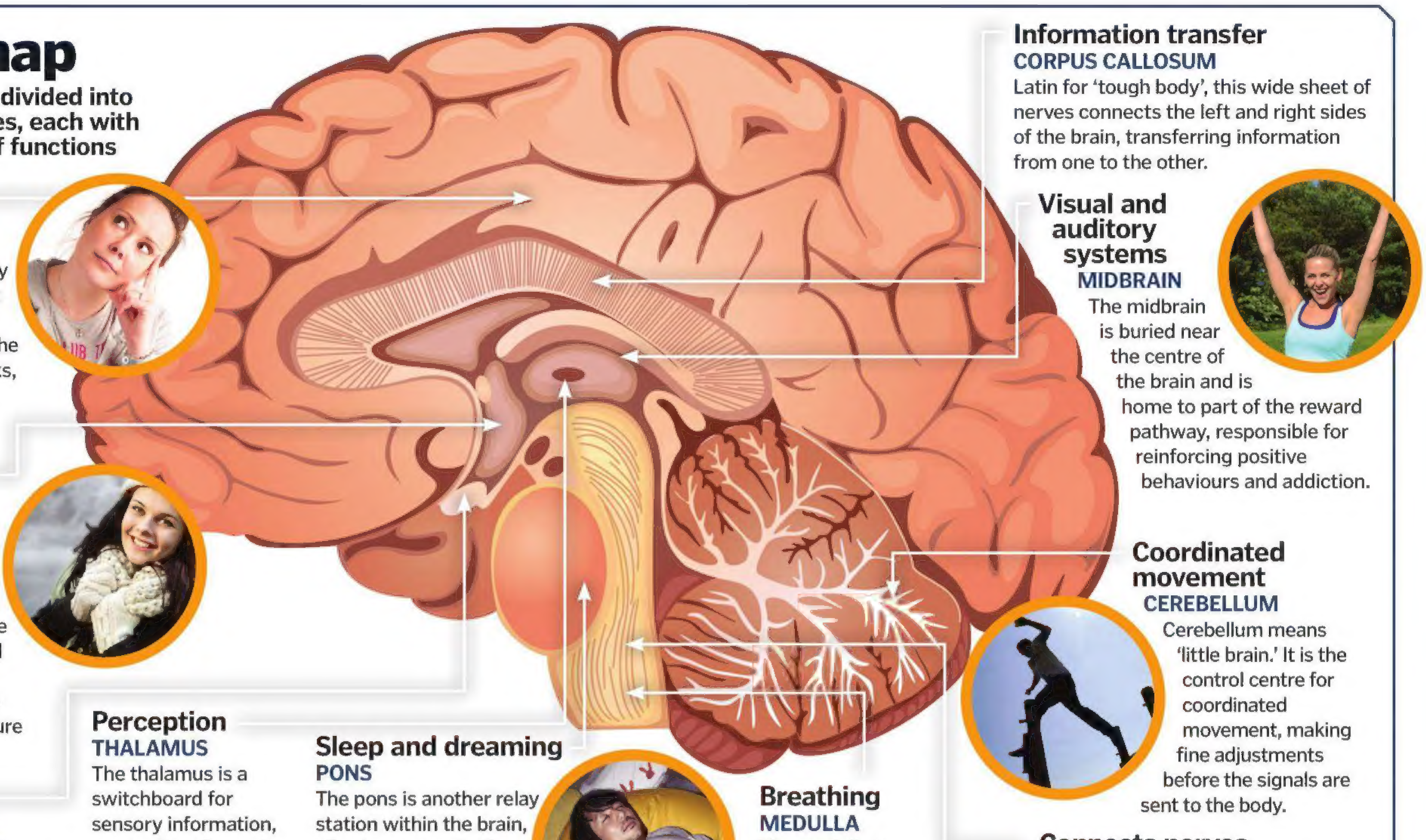
Microglia
4 The brain is sealed off from the immune system, but specialist cells, microglia, are present for protection. They are inactive most of the time to prevent accidental damage to the brain.

Endothelial cells
5 The capillaries that supply blood to the brain are lined with these. They are tightly connected to one another, to restrict movement of chemicals in and out of the brain.

DID YOU KNOW? *When Albert Einstein died in 1955, pathologist Thomas Harvey stole his brain, cut it up and preserved it in jars*

Brain map

The brain can be divided into distinct structures, each with a specialist set of functions



Memory
CEREBRUM
The cerebral cortex makes up the majority of the human brain. It is divided into four lobes, which handle the most complex of tasks, including planning, memory and vision.

Temperature and hydration
HYPOTHALAMUS
The hypothalamus is responsible for maintaining equilibrium within the body. It monitors and adjusts a variety of vital parameters, like the body's temperature and hydration.

Hormones
PITUITARY GLAND
This pea-sized gland is connected to the hypothalamus and produces hormones, passing on chemical messages instead of electrical impulses.

Perception
THALAMUS
The thalamus is a switchboard for sensory information, connecting the parts of the brain and body involved in perception and movement. It also controls the sleep/wake cycle.

Sleep and dreaming
PONS
The pons is another relay station within the brain, allowing nerves in the cerebellum to contact those in the cortex. The pons also plays an important role in the sleep cycle and dreaming.

Breathing
MEDULLA
The medulla is responsible for the involuntary functions that keep us all alive, like breathing, swallowing and heartbeat.

Information transfer
CORPUS CALLOSUM
Latin for 'tough body', this wide sheet of nerves connects the left and right sides of the brain, transferring information from one to the other.

Visual and auditory systems
MIDBRAIN
The midbrain is buried near the centre of the brain and is home to part of the reward pathway, responsible for reinforcing positive behaviours and addiction.

Coordinated movement
CEREBELLUM
Cerebellum means 'little brain.' It is the control centre for coordinated movement, making fine adjustments before the signals are sent to the body.

Connects nerves
BRAIN STEM
The brain stem marks the end of the brain and connects the nerves to the spinal cord. It contains two distinct structures, the pons and the medulla.

The human brain is the most complicated structure in the known universe. It has taken hundreds of millions of years of evolution to construct, and over the last seven million years, it has tripled in size. It weighs little more than a bag of sugar, but packed inside it are 86 billion neurones, linked together by over 100 trillion connections in a network more powerful than even the most advanced supercomputers ever built.

By far the largest part of the human brain is the forebrain, and like the brains of other mammals, it is covered in a thick layer of neurones known as the cerebral cortex. But in humans, this layer has been massively expanded. The human cerebral cortex has 1,000 times as many neurones as the same structure in a mouse, and it has not yet stopped evolving.

The smallest processing units in the cortex are known as neocortical columns, where each contains thousands of different connections. Over the course of evolution, these neocortical columns have been duplicated over and over again, until space in the skull started to run out. The cortex developed deep ridges and folds to fit more and more processing power into the same tiny space, and if unfolded, would cover an area measuring two square metres (21.5 square feet).

The neurones that make up the brain crisscross over one another in a vast network and each individual cell makes up to 10,000 connections, building the most complex circuit in history.

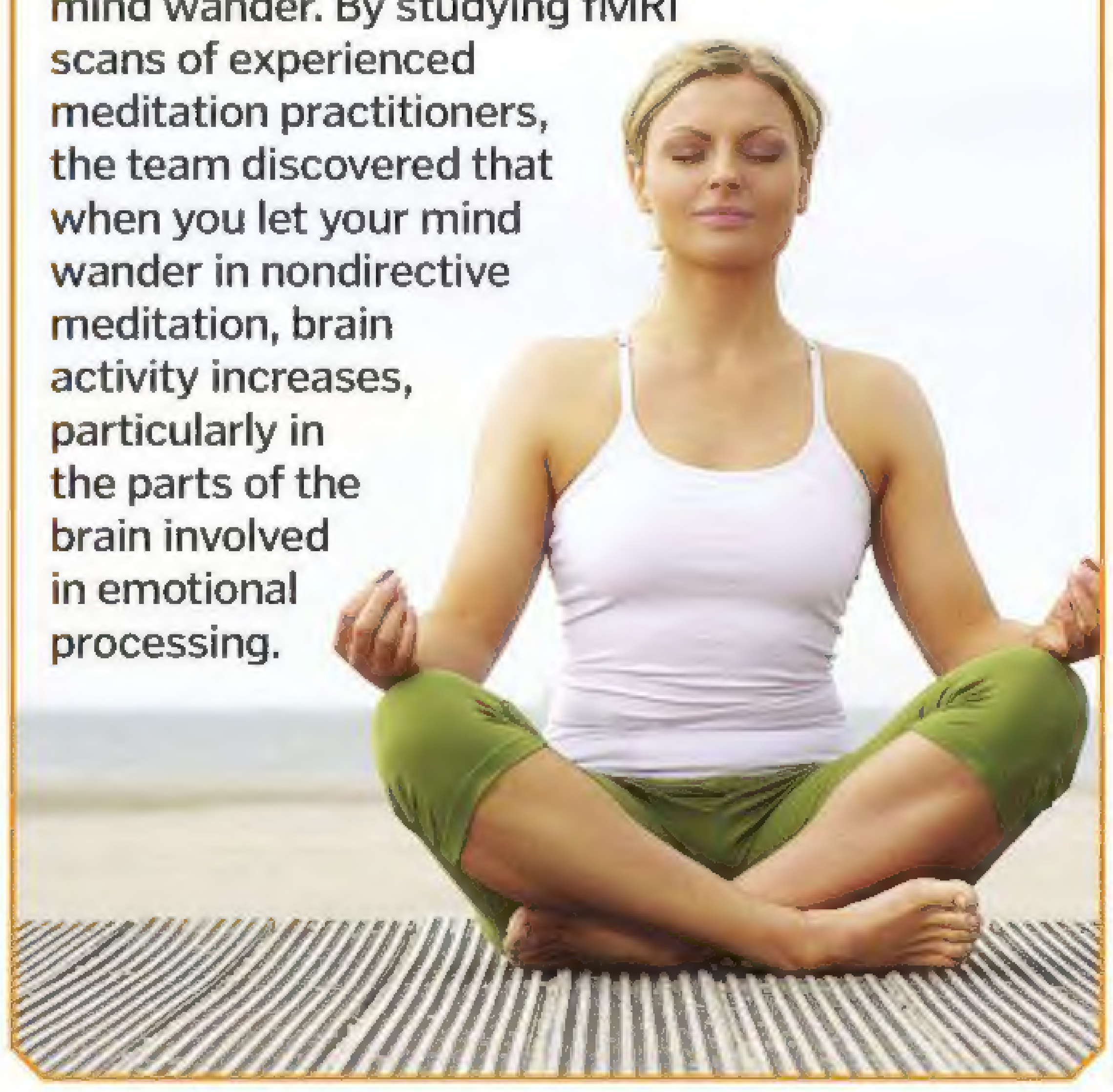
In 2013, a team at the Centre for Regenerative Therapies in Dresden, Germany, examined the formation of neurone connections in cloned mice. They wanted to learn how much the structure of the brain is influenced by life experience. Because the mice were clones, each was genetically identical, meaning that any differences in their brains would be purely down to their environment. The mice lived in large cages, with lots of toys and places to explore, and after just a few months, differences became apparent in their brains. The most excitable, outgoing, curious mice had many more new nerves and new connections than their lazier counterparts; their brains had adapted as they learnt.

While the underlying fabric of the brain is the same, every neurone in every brain is different, and each makes its own unique path. Every ▶

Finding peace

Meditation has been practiced for thousands of years as a means to relax, think, or to find enlightenment. Now, an international team of researchers, based in Norway and Australia, are collaborating to understand why it is such a powerful tool.

There are two types of meditation; concentrative, where a person focuses on specific thoughts; and nondirective, where they let their mind wander. By studying fMRI scans of experienced meditation practitioners, the team discovered that when you let your mind wander in nondirective meditation, brain activity increases, particularly in the parts of the brain involved in emotional processing. ▶



"Projects like EyeWire provide a biologically accurate picture of what is going on inside the human brain"

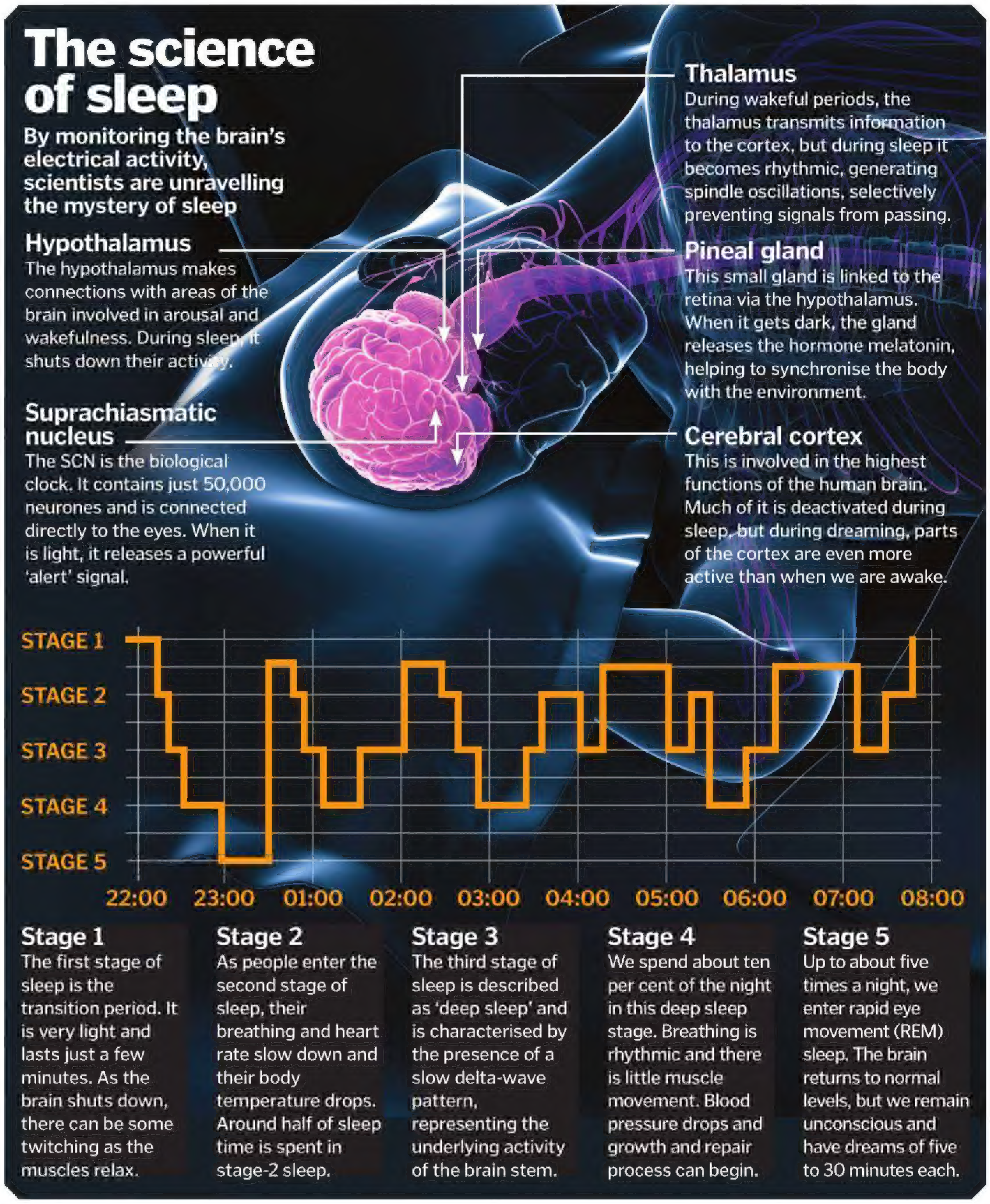
brain is wired differently, and the unique set of connections is based on experiences.

Mapping the connections in the human brain is an enormous task and work is ongoing. The Human Connectome Project, launched in 2009, is designed to map the intricate connections between all of the neurones in the human brain, in an effort analogous to the Human Genome Project. Computers can be programmed to trace the paths of neurones through brain-scan images, but even the most advanced machines make mistakes, and everything has to be double-checked by a human.

As an alternative, some research teams are trying a new approach, where instead of using computers to analyse the data they are using volunteers. In 2011, the online game *Foldit* made the headlines when players managed to solve a decade-old biological question. By tapping into the spatial skills of videogamers, researchers used volunteers to solve three-dimensional protein puzzles that a computer would struggle to complete. By simply playing the game, hundreds of people worked together to help solve the structure of a protein made by a simian retrovirus that causes AIDS-like symptoms in monkeys.

This approach is now being extended to the field of neuroscience and crowd-sourcing is being used to map the connections between neurones in the back of the eye. Tracking the intricate pathways of neurones in the brain is a difficult task for computers, but people are much better at spotting patterns.

EyeWire is a project designed to map the nerve connections in the human retina. Players are given a half-finished neurone and asked to work through slices of the brain, colouring in the connections. Each cube section is manually checked multiple times by different people, so ▶



The developing brain

Baby
In order to fit through the birth canal, human babies must be born well before their brains have finished developing, so their brains grow rapidly in their first years. Experiences prompt the development of new connections between nerves, and by the time a baby is two years old, it has 1.5 times as many synapses as an adult.

Infant
Support cells, known as glia, provide protection, insulation and nutrition for the brain's nerve cells. Throughout childhood, they continue to migrate and grow. During the first two to three years of a child's life, the insulating white matter of the still-developing brain begins to form.

Child
By the age of ten or 11, the rapid development of new connections in the brain has ended and a period of trimming and pruning begins. Instead of creating extra pathways, the brain focuses in on the most important, strengthening and insulating those that are used more often and losing ones that are no longer valuable.

NEURONES **86 billion** · OXYGEN USAGE 20% · LENGTH 17cm · MASS **1.4kg** · SYNAPSES **100 trillion** · PART OF BODY WEIGHT **2%**

DID YOU KNOW? *You sleep for around a third of your life and have around five dreams every night*

Making memories

The human brain has an amazing capacity for retaining information

SENSORY MEMORY
The body is constantly bombarded by sensory signals and most incoming sensory information is retained for less than a second before it is forgotten.

TRANSFER
The hippocampus integrates incoming sensory information, collecting it together as a single experience. It works together with the cortex to prioritise which information to store and which to forget.

SHORT-TERM MEMORY
Without concentrating too hard, short-term memory can hold around seven items for 20 to 30 seconds. Collecting information into discrete chunks, like splitting a phone number up into sections, can help the brain retain more.

IMPLICIT MEMORY
These types of memories do not require conscious recall and are often based on motor skills. By repeating tasks, like riding a bike or playing the piano, pathways become automatic.

EXPLICIT MEMORY
Explicit memories are accessed consciously. They can be stored as episodes, linked to a specific event or place, or stored by category as more abstract knowledge.

RECALL
Human memory is associative; it works by linking pieces of information together. Memories are not stored as individual entities, but reconstructed using several different parts of the brain.

NEURONE CHANGES
If a synapse is used repeatedly, it becomes increasingly sensitive to stimulation, producing more receptors and strengthening the connection.

ACOUSTIC ENCODING
Short-term memory tends to be based on sound, also known as echoic memory. When trying to remember a phone number, it often helps to rehearse it vocally in your head.

CONSOLIDATION
Once the trace of a memory is formed, the pathway can be consolidated with use. The more often a synapse is used, the stronger it becomes.

LONG-TERM MEMORY
The hippocampus is essential for the transfer of memories from short to long-term storage. Some of this memory consolidation happens in dreaming as the brain rehearses the day's activities.

RECOGNITION
The brain is very good at making associations, and incoming information is compared to stored data, allowing us to quickly recall things we already know or have experienced before.

ASSOCIATION
Memories are rarely stored in isolation and one pathway is linked to others. Recognition and recall can both trigger other related memories.

SEMANTIC ENCODING
Instead of being linked to an audio memory, long-term memories tend to be stored more abstractly, by concept. Other memories are stored as sensory echoes, allowing entire experiences to be remembered and reconstructed.

Teenager
Trimming and adjusting the brain starts at the back and works forward, continuing into the teenage years. The prefrontal cortex, involved in planning, judgement and emotional control, is the last to be finished. Research also suggests that adolescents' body clocks are wired differently, so they naturally go to bed and wake up later.

Adult
Most growth and remodelling is complete by our early-20s, but new connections continue to form in the adult brain, albeit at a much slower rate than in children. Staying active and providing the brain with engagement and stimulation strengthens existing connections, and new pathways continue to form as we learn.

Old age
Damage to the brain cannot easily be repaired, so as it ages, signs of wear start to appear. Connections are lost as nerve cells wither, or as debris builds up between synapses, and gradually mental function can decline, leading to age-related illnesses like Alzheimer's disease and Parkinson's.

"At the University of California [...] researchers are using electricity to selectively erase memories"

if someone makes a mistake it is averaged out by the community. More experienced players oversee the work and can make changes if they feel they are needed. This approach speeds up the process by thousands of times.

Although projects like EyeWire provide a detailed and biologically accurate picture of what is going on inside the human brain, rebuilding the entire structure using this method will still take decades. The alternative is to simulate the brain, taking what we already know and using it as a scaffold to build the parts we have yet to study. By going back and testing the model brain against the real data, scientists can check that their simulation is working as it should.

Japan's K Computer is one of the fastest and most powerful in the world, and in 2014, 83,000 of its processors were combined in order to simulate one per cent of one second of human brain activity. This was a huge achievement, but it took the machine 40 minutes and barely represented a fraction of the power of the human brain.

The problem is that most modern computers are built on architecture completely different to the human brain. The brain is made up of processing cores, capable of specialising to perform highly specific tasks. They are less precise, but have much more flexibility, and most importantly, the capacity to learn. Memories are not stored in one particular place, and are instead distributed across the network. In contrast, modern computers use programs in order to decide what to do, and they store elements in a hierarchical memory.

In 2013, the European Commission funded the Human Brain Project with a grant of €1 billion (£800 million/$1.3 billion) in order to accomplish just that. This ambitious, ten-year endeavour aims to develop cutting-edge computational tools to assist in the understanding of brain function, bringing together the fragments from different disciplines and providing an unprecedented map of human brain activity. The Human Brain Project hopes to use this information to build a supercomputer capable of simulating the network that makes up the human brain. They estimate that it would take one laptop to simulate the activity of one neurone and are working closely with IBM to develop powerful neuromorphic supercomputers.

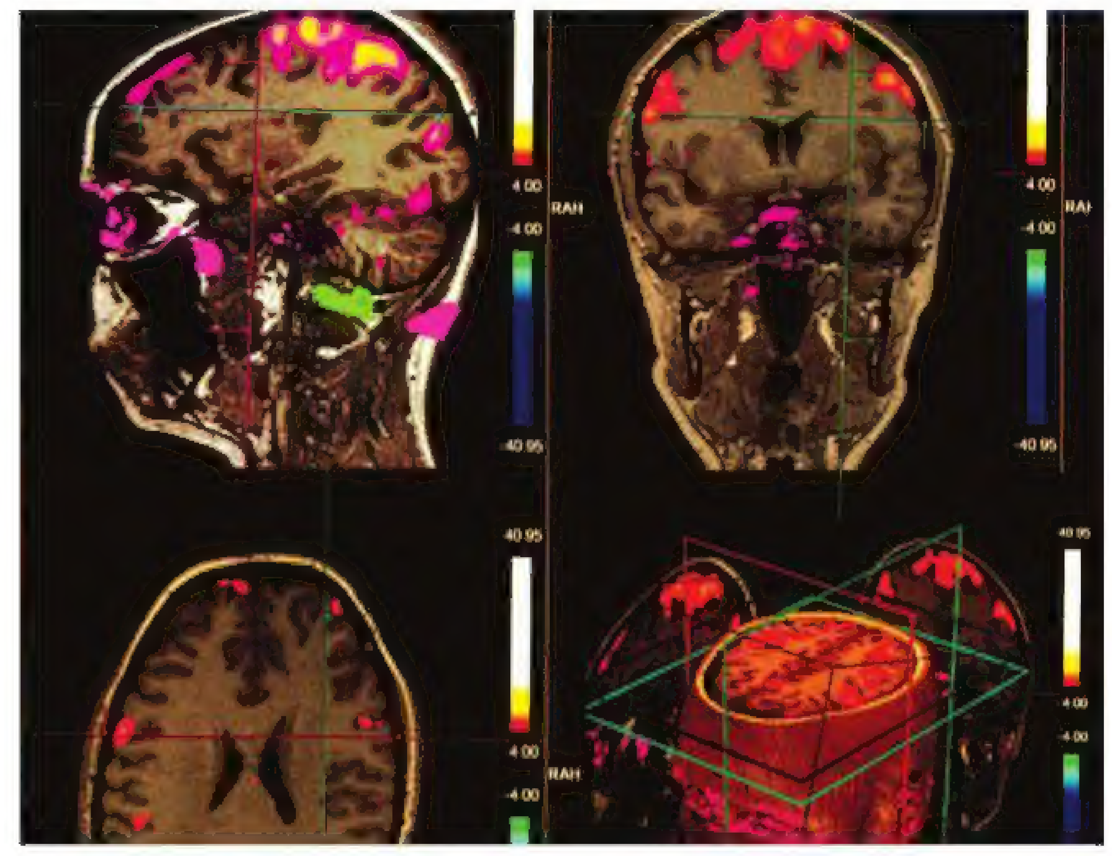
Neuromorphic chips are computer chips modelled on the architecture of the human brain. IBM released a chip modelled on the human brain in 2014. Known as the SyNAPSE chip, it has one million 'neurones' connected by 256 ▶

Imaging the brain

Take a look at the most common techniques used to study the living brain

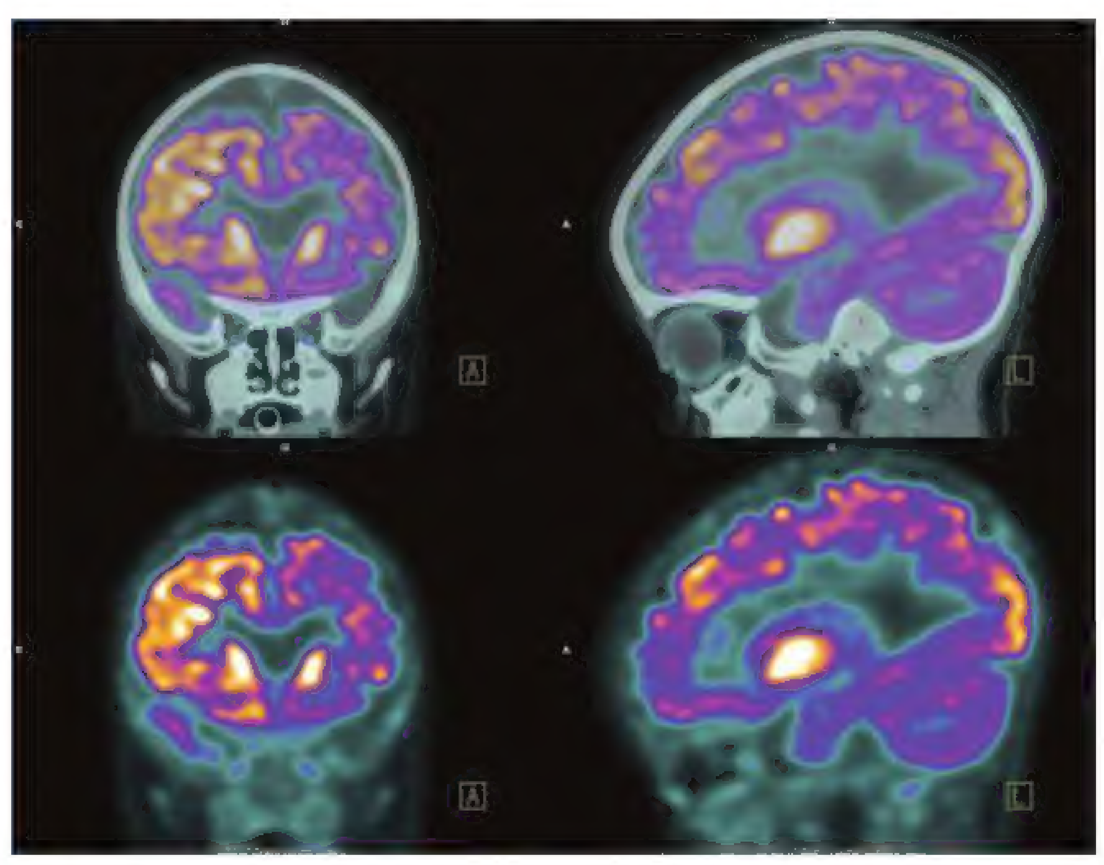
CT

Computed tomography (CT) scans use X-rays to build a three-dimensional image of the brain. The radiation travels at different speeds through different tissues, allowing a density map to be produced. It provides purely structural information and is useful for identifying tumours.



fMRI

Functional Magnetic Resonance Imaging detects the amount of oxygen present in the blood, allowing brain activity to be mapped. When regions of the brain become more active, their demand for blood rises and they light up on the image. It captures a picture of the activity of the entire brain every two seconds.



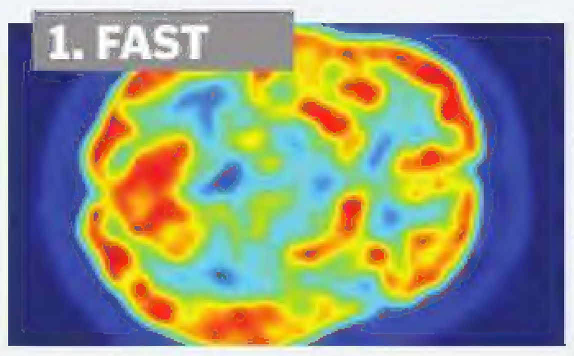
PET

Positron Emission Tomography uses safe radioactive isotopes to measure brain activity. By labelling oxygen or sugar with radioactive tags, blood flow in the brain can be monitored. The tags emit low-energy radiation and as blood is diverted to active regions of the brain, the emissions pinpoint the locations.

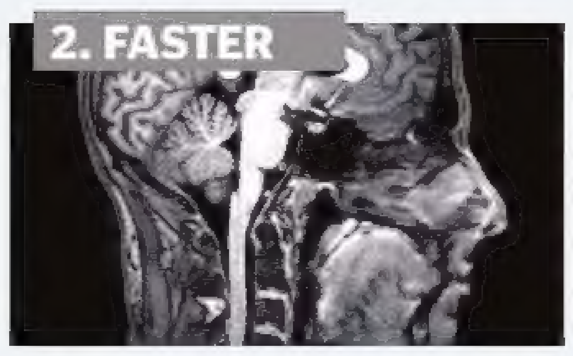
EEG

Electroencephalograms take advantage of the electrical signals produced by nerves to produce a map of brain function. Electrodes placed on the scalp are able to detect the patterns of nerve activity beneath the surface. This technique is particularly useful for sleep studies.

HEAD 2 HEAD
SCANNING BRAINS



PET
Compared to other imaging techniques, radiation-based methods like PET scans are relatively slow, where it takes several minutes to complete a scan.



fMRI
Functional MRI captures an image of the activity of the brain every two minutes, allowing changes to be monitored closely.

Magneto-encephalopathy
Using sensitive magnetometers, scientists are able to record the electrical activity of the brain in real-time.

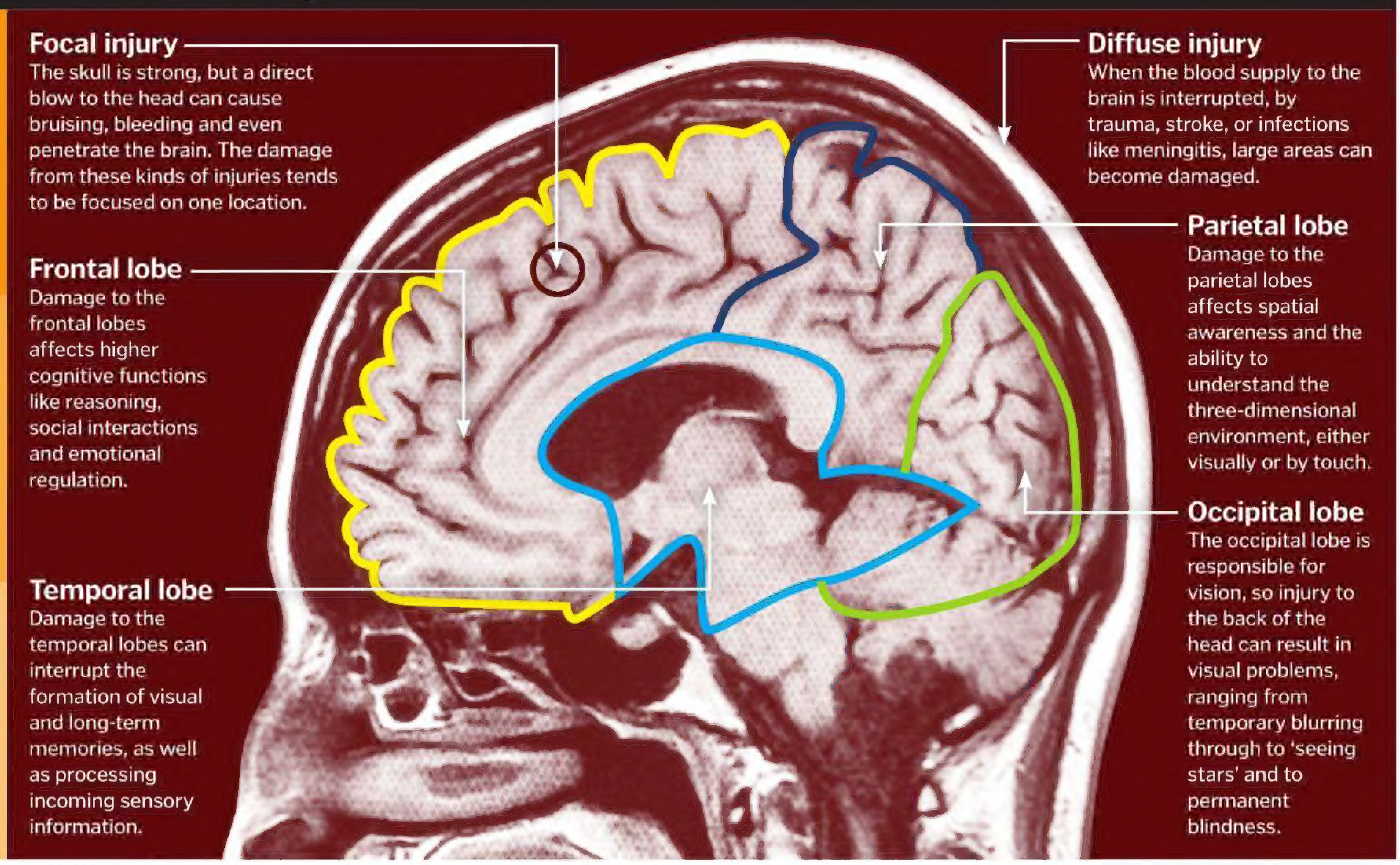
DID YOU KNOW? A human brain weighs around four times as much as a chimpanzee's brain

Brain damage
Different injuries affect the brain in different ways

SEVERE
If the injury is severe, the patient is no longer able to respond to sensory stimulation. Their eyes remain closed and there is no response at all to verbal cues.

MODERATE
When brain injury is more severe, verbal communication starts to break down and patients no longer respond normally to pain.

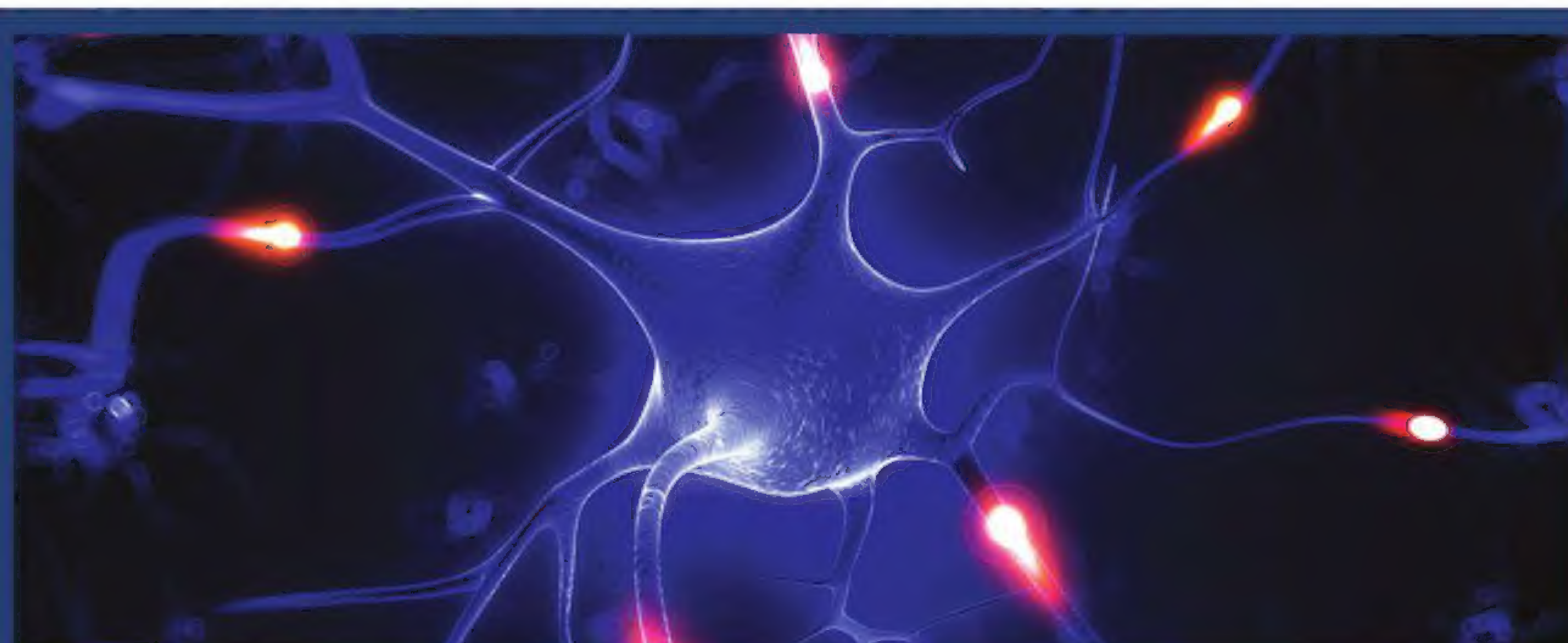
MILD
With mild brain injury, patients may be confused, but they remain aware, conscious and conversational.



Can the brain heal?

The human brain has limited capacity for repair, so once a region is injured, it cannot be replaced. The damaged cells are removed and support cells known as astrocytes divide to form a wall around the gap to seal off the area. The space then becomes filled with fluid. However, all is not lost.

The human brain is a remarkable organ and although it cannot repair itself as such, it is able to adapt. Nerves are not fixed in their function, or their connections, so if a part of the brain is injured, new connections can be made to bypass the damage. The amount of function that can be regained depends on the location and severity of the injury and can be greatly aided by rehabilitation, encouraging the formation of new pathways in the brain.



million 'synapses.' They are arranged into 4,096 'synaptic cores', which function in parallel with one another, just like the processing cores in the brain. Just like the brain, they operate on demand and can compensate if one core happens to fail.

By feeding these computers with inputs that mimic biological signals, scientists can then examine the electrical activity and can see where information is being processed and stored. The project is a collaboration between over 100 institutions in 24 countries.

New technology is the key to modelling a structure as complex as the human brain, and other international efforts are also in place to provide new technology. In 2013, US President Barack Obama announced the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative. The NIH (National Institutes of Health) will allocate £24 million ($40 million) in 2014 to develop new technologies to find the best way to understand the brain. In order to break the brain down and rebuild it accurately, the project will combine silicon-based techniques and advancements in stem-cell biology, brain imaging and medical drug development.

The practical applications of this future technology are incredible, but we are already able to interface with the brain in more ways than ever before. Light-sensitive retinal implants can restore sight to the blind by sending electrical signals to the optic nerve, while auditory brainstem implants communicate sound signals directly to the brain in patients who are profoundly deaf.

However, one of the most incredible technological developments of all is the BrainGate system, first revealed in 2006 and now undergoing clinical trials. The technology uses a sensor implanted on the motor cortex of the brain to pick up electrical signals generated when the patient thinks about moving. These signals are then decoded by a computer program and sent to a ▶

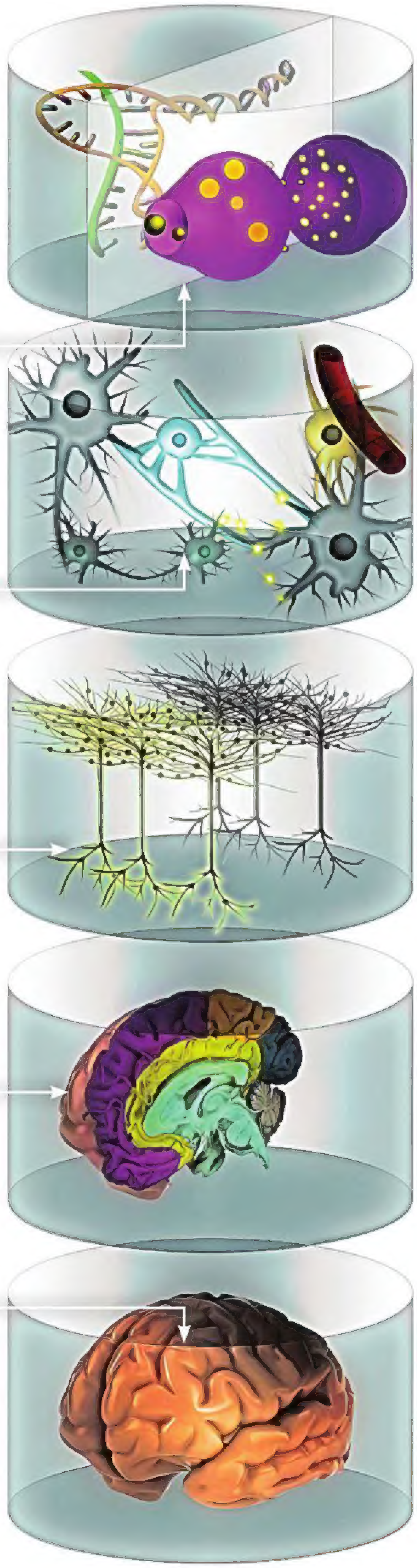
"Player one thinks about firing the cannon, and fractions of a second later, player two pushes the button"

Cutting-edge neuroscience

The human brain is one of the most complex structures in the known universe and understanding how it works is an enormous scientific undertaking. Modern neuroscience brings together experts from a huge array of fields and by using a combination of the most advanced technologies, medical techniques, biological research and computational modelling, scientists are finally beginning to untangle the many profound mysteries of the human brain.

Building a brain

Large-scale projects aim to simulate the human brain at every level



DNA and neurotransmitters

At the molecular level, scientists are able to manipulate the 3D structures of proteins using computer programmes, and to model the effects that changes might have. Such techniques are hugely useful in drug design.

Nerves and support cells

In order to gain a proper understanding of how the brain functions, many scientists advocate a bottom-up approach. By creating digital neurones based on the underlying rules and principles of biology, it is hoped that the complex network of the brain can be simulated.

Neural pathways

Some projects aim to map all of the connections in the human brain, generating a 3D representation of the intricate wiring. Others aim to simulate the process, allowing the computer to make its own connections based on biological rules.

Lobes and structures

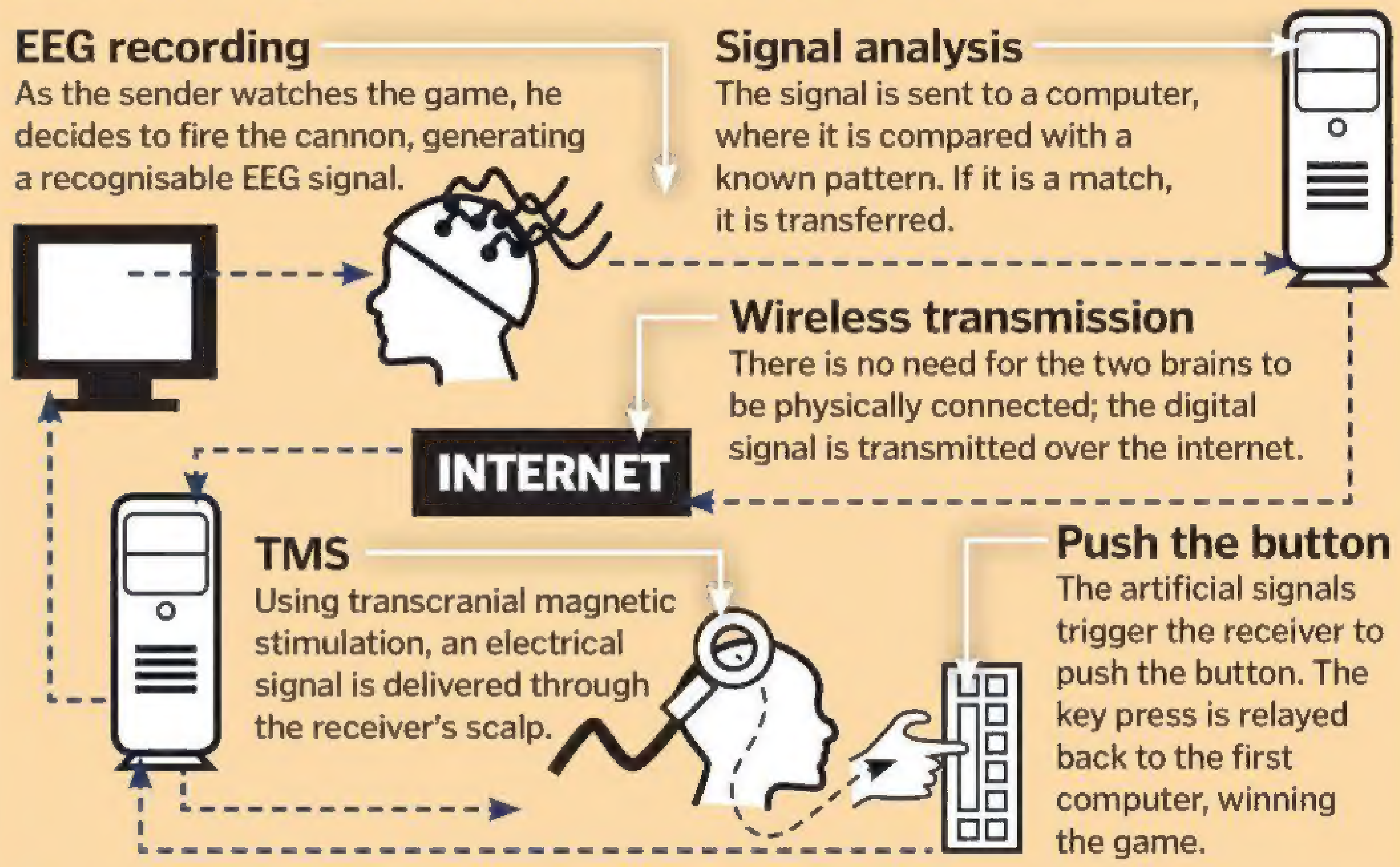
Simulations will allow information about different structures in the brain to be integrated, enabling scientists to more closely examine the interactions between different areas, or even to remove one region and study it in isolation.

Whole brain

In 2013, the K Computer in Japan carried out one second of simulated human brain activity. With 705,024 processor cores, it took the machine 40 minutes to simulate a network just one per cent of the size of the human brain. Advanced processors due in the next ten years will increase this capability significantly.

How mind control works

Simple equipment and complex computer programming allow our thoughts to be transmitted over the internet



Mind control

In a groundbreaking experiment in 2013, researchers at the University of Washington successfully linked two human brains together and proved their principle with a video game.

The city is under attack by pirates, where player one, the sender, must intercept their rockets. They can see the screen and are armed with a cannon, but they do not have a keyboard and cannot press 'fire'. Player two, the receiver, is sitting in another room; he cannot see the game, but he does have a keyboard. Player one thinks about firing the cannon, and fractions of a second later, player two pushes the button, saving the city and winning the game.

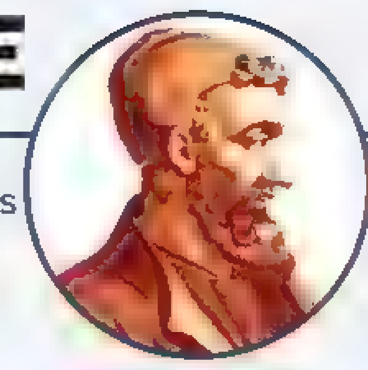
Player one was wired up to an electroencephalogram (EEG) and his brain activity was being monitored. When he was thinking about pressing the button, there was a characteristic signal in the 'mu band' of the EEG, triggering the program to send a wireless signal to player two.

Player two was wearing a specially designed coil on his scalp that generated a magnetic field, positioned over the part of the brain that controls contraction in the right hand. The signal from player one was converted into magnetic stimulation, which in turn triggered electrical activity in the brain, causing player two to involuntarily fire the cannon.

KEY DATES
HISTORY OF NEUROSCIENCE

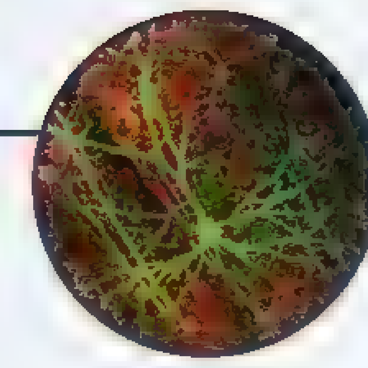
1700 BCE An Egyptian surgeon records details of his patients, producing the first written example of the word 'brain.'

130-200 CE Greek surgeon Galen suggests the brain is responsible for sensory perception and the control of movement.



1837 Czech Johannes Purkinje describes a nerve cell for the first time; the large, branching neurones of the cerebellum.

1861 Pierre Paul Broca identifies the region of the brain responsible for speech, now known as 'Broca's area.'



1906 Camillo Golgi and Santiago Ramón Y Cajal share the Nobel Prize for demonstrating that the brain is a network of neurones.

DID YOU KNOW? Your brain produces enough electricity to power a light bulb and consumes 20% of the oxygen you take in

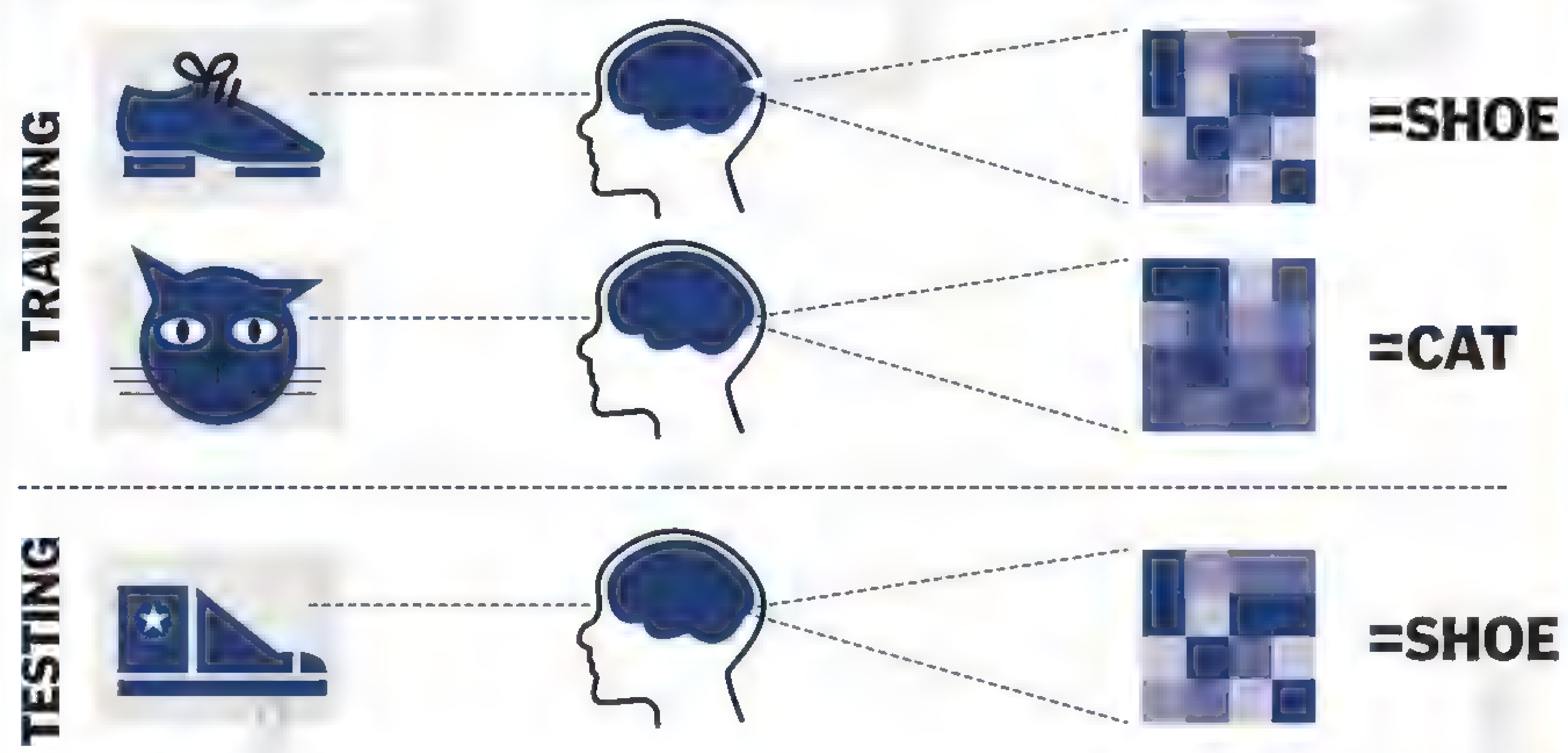
Decoding the brain

Computer programmes can learn to decode brain-scan data and essentially read our thoughts

Training images
The program is trained using a series of images, alongside their corresponding fMRI patterns.

fMRI scan
Functional magnetic resonance imaging is used to identify the parts of the brain activated by different visual stimulation.

Voxel pattern
The fMRI data is stored as voxel patterns, three-dimensional grids of information.



Test image
When the subject is shown a new image, the program searches through its training database to find the nearest match.

Identification
If the program cannot find an exact match, it will use its training data to find a best estimate.

A machine that can read your mind

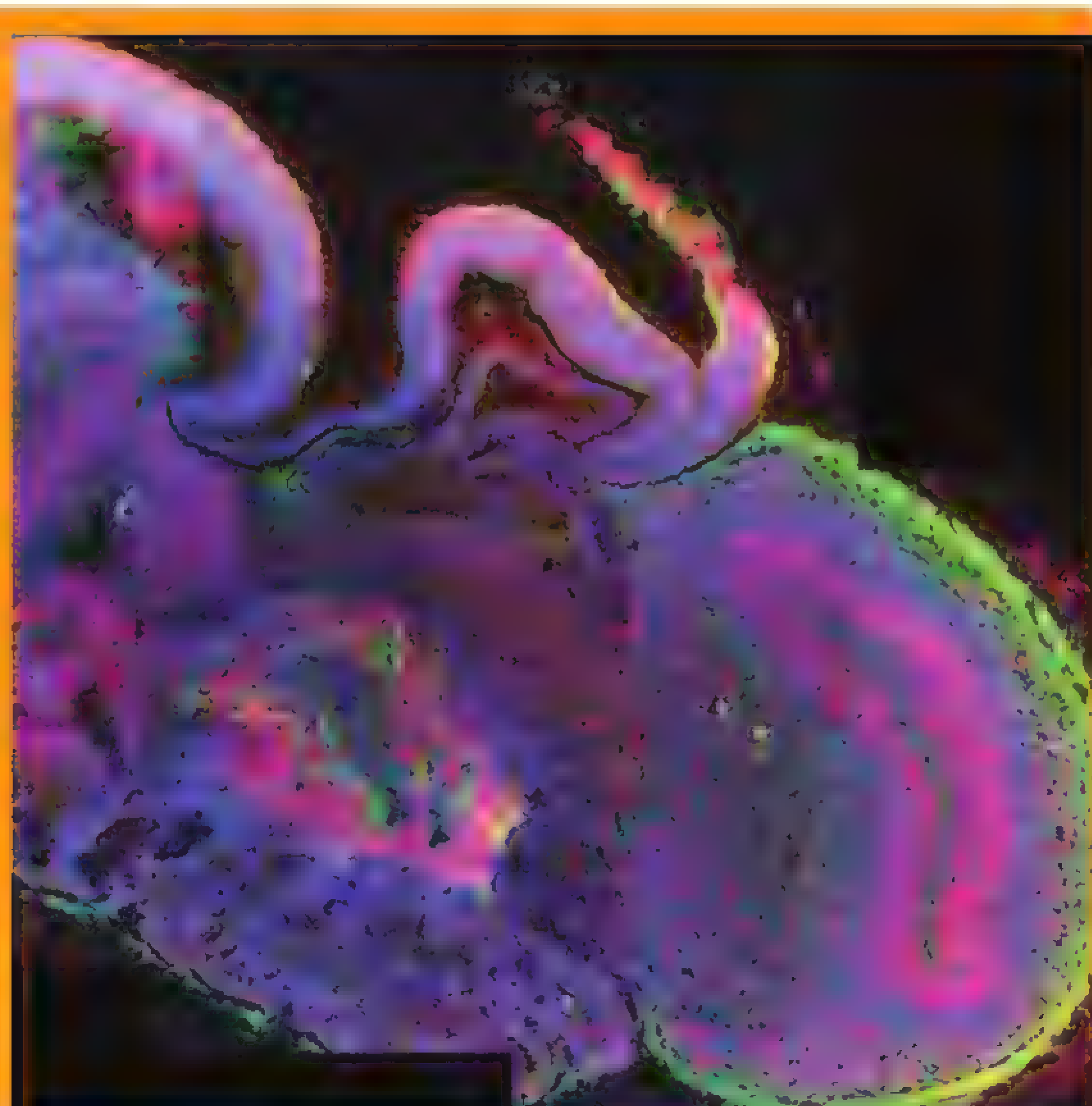
Have you ever wished someone else could see what you can see? A team at the University of California, Berkley, have developed a program that can tell what film you are watching just by reading your brain activity. The program can even read the exact image you see and display the moving mental images on a screen.

Volunteers were shown hours of video clips and for each one, their brain activity was mapped using functional magnetic resonance imaging (fMRI). The program was then trained to associate patterns of brain activity with their corresponding images.

Using this data set as a reference, the program was the shown new fMRI data recorded as people as they watched unknown clips. The program was able to compare the new data against its training data and guess what the test subject was watching by compiling and averaging the closest matches in to moving collages. The resulting pictures were eerily close to the original clips.

Get involved with EyeWire

Growing a brain



prosthetic limb. By carefully training the program to recognise specific signals, patients are able to move their bionic hands using just the power of their brains.

Taking electrical brain interfaces one step further, at the University of California, San Diego, researchers are using electricity to selectively erase memories. They have shown that by using particular frequencies of electrical pulses they can produce changes in the nerve cells in the brains of rats, making them forget traumatising experiences in their past.

As we continue to learn more about the connections in the brain, the possibilities for interacting with it will only continue to increase. The field of neuroscience is advancing faster than ever before, and huge international collaborations, like the Human Brain Project and the BRAIN initiative, are bringing mountains of research data together, creating resources that will revolutionise the field of neuroscience.

The puzzle of the human brain has been vexing scientists, doctors, and philosophers for thousands of years and understanding how it works is perhaps the most challenging problem in the history of science. However, with a combination of powerful new technology and international collaboration, the complexity of this mass of neurones is starting to unravel. Very soon, we might even be able to rebuild a functioning digital brain from the bottom up.

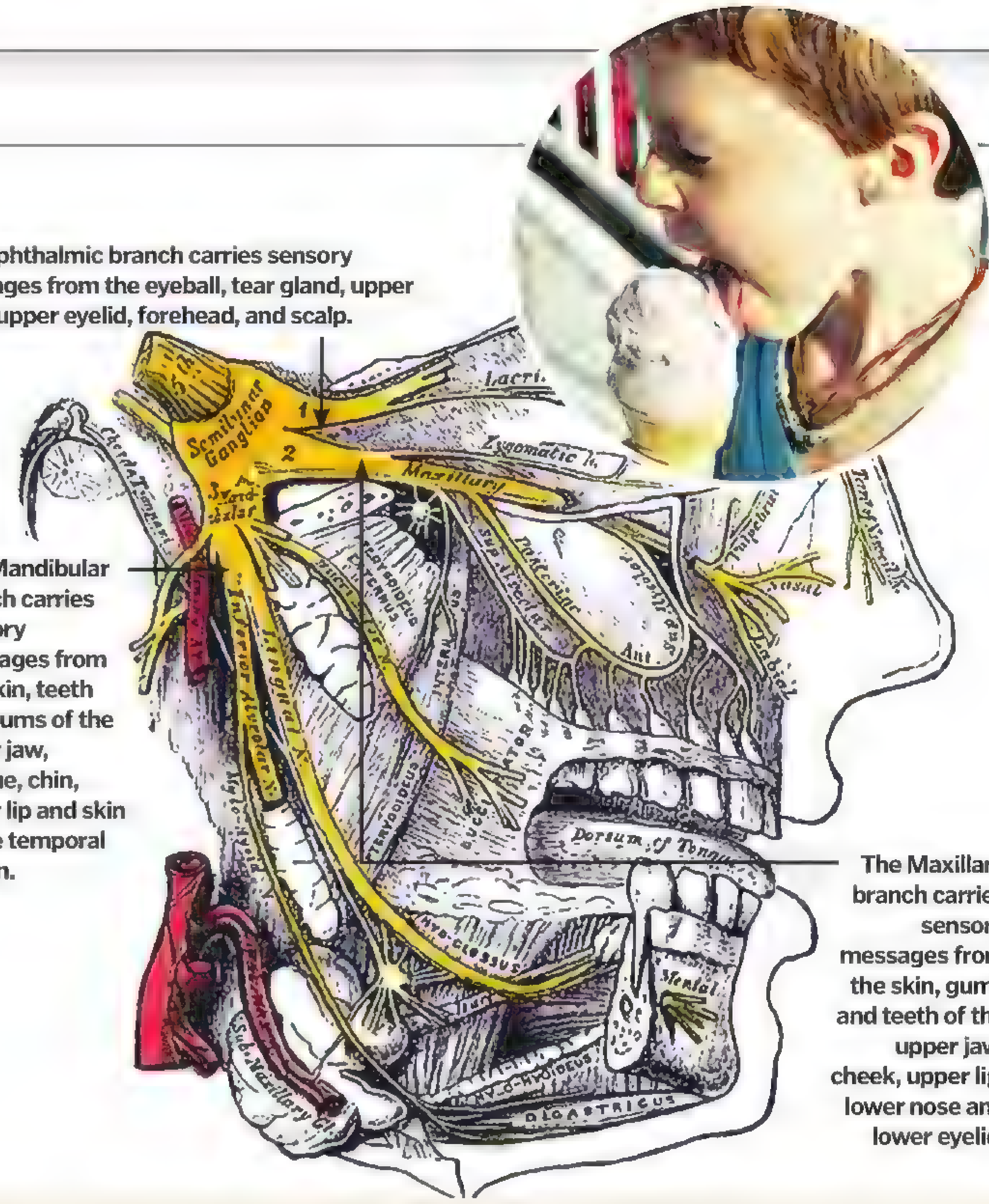
What is 'brain freeze'?

That intense pain you sometimes get when you eat ice cream too fast is technically called sphenopalatine ganglioneuralgia,

The pain of a brain freeze, also know as an ice cream headache, comes from your body's natural reaction to cold. When your body senses cold, it wants to conserve heat. One of the steps it takes to accomplish this is constricting the blood vessels near your skin. With less blood flowing near your skin, less heat is carried away from your core, keeping you warm.

The same thing happens when something really cold hits the back of your mouth. The blood vessels in your palate constrict rapidly. When the cold goes away, they rapidly dilate back to their normal state.

This is harmless, but a major facial nerve called the trigeminal lies close to your palate and this nerve interprets the constriction/dilation process as pain. The location of the trigeminal nerve can cause the pain to seem like its coming from your forehead. Doctors believe this same misinterpretation of blood vessel constriction/dilation is the cause of the intense pain of a migraine headache.



Nerve cells

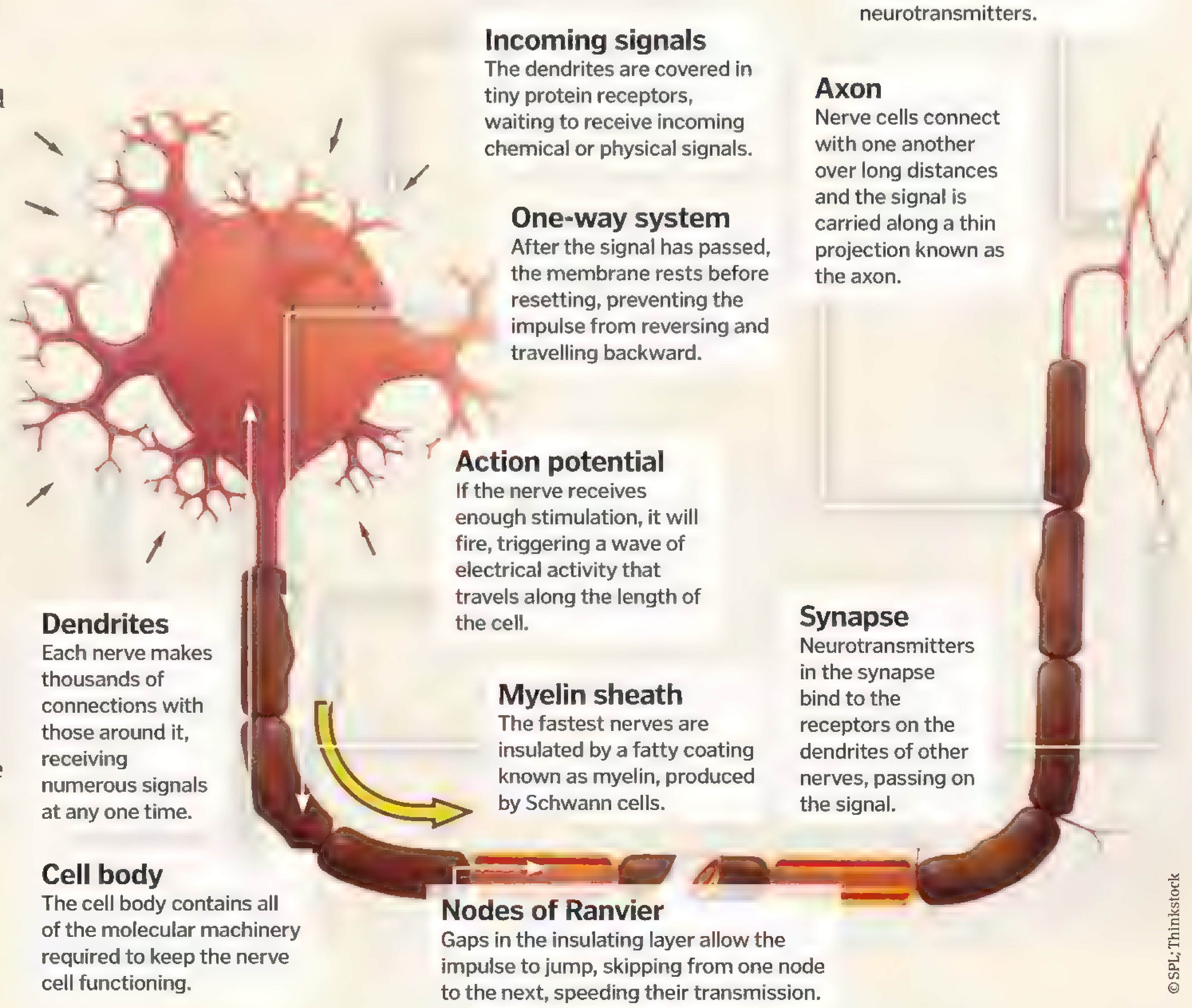
Learn about the network of messenger cells in your body

Neurones are cells in your nervous system that transmit messages around the body. They do this in the form of electrical signals called nerve impulses. At rest, the cells expend huge amounts of energy pumping positively charged sodium ions (Na^+) out into the surrounding fluid. This leaves the inside of the cell slightly negatively charged. The sodium ions are attracted to the negative charge, but they are unable to cross the cell membrane and therefore become trapped on the outside, waiting for an opportunity to re-enter the neurone.

The outside of the cell is covered in voltage-activated channels; pores wide enough to fit a sodium ion, but which only open when the membrane voltage is high enough. If the neurone receives activation signals, tiny amounts of sodium are allowed to leak in, causing the voltage across the membrane to rise, opening the channels. As the ions flood the cell, more channels are activated further along the axon, initiating a domino effect. This transmits the signal to the synaptic terminal. Here, prepackaged neurotransmitters are released into synapse, where they deliver the message to other cells.

Inside a nerve cell

Neurones are some of the longest and most highly specialised cells in the human body



RECORD BREAKERS
LONGEST COMA

37yrs 111days

In 1941, Elaine Esposito received a general anaesthetic for a routine operation. She never woke up. Aged six at the time, Elaine remained in a coma until 1978, when she finally died at the age of 43.

The biology of comas

It means 'deep sleep' in Greek, but a coma is no such thing...

A coma is a state of unconsciousness in which the brain is alive but functioning at its lowest level of alertness. Normally the brain transmits continuous chemical signals from the cerebral cortex (the outer layer) to the brainstem (which is attached to the spinal cord). The cerebral cortex is responsible for high-level thoughts such as feelings, while the brainstem regulates automatic functions like the heart pumping.

In order to 'talk' to each other signals are channelled between the brainstem and the cerebral cortex via a neural pathway called the reticular activating system (RAS). The RAS is like the brain's light-switch – turn it off and you switch off consciousness. When functioning normally the RAS sends messages from an area called the reticular formation, through the thalamus (a mass of neurons at the top of the brainstem) to the cerebral cortex.

During sleep the neurons in the RAS fire at a lower rate but are still active. But in a coma the activity is too minimal for the cortex to process information, leaving the person without awareness.

A coma occurs when the RAS is disrupted by brain injury or illness. Meningitis, for example, can cause swelling in the brain which presses on blood vessels and blocks oxygen to vital areas.

Doctors grade a patient's degree of consciousness with the Glasgow Coma Scale (GCS), measuring eye opening, as well as verbal and motor responses. The lower the score, the deeper the coma.

A person in a coma may die, recover or transition into a vegetative state. A person in a vegetative state has more lower-brain function (actions like breathing) and slightly more upper brainstem functions such as being able to open their eyes. A coma is not the same as 'locked-in syndrome' where the person is fully conscious but paralysed.

Coming out of a coma

Recovery depends on the cause of the coma. Infection-induced comas may reverse with antibiotics, while excess pressure may resolve by draining fluid. Comas rarely last more than two to four weeks, but recovery is gradual. Patients may be alert for only a few minutes, progressing to longer periods. Their outcome relates to their Glasgow Coma Scale result – those who scored lowest in the first 24 hours will likely die or remain in a vegetative state, while those who score at the higher end may make a full recovery. Coma survival rates are around 50 per cent. After a coma the patient may only recall memories after coming to and will usually wake in a profound state of confusion, not knowing how they got there. However, they tend to regain brain function gradually, often with the help of physiotherapy and occupational therapy to relearn basic skills like walking, talking and eating.

Brain activity comparison

See a healthy brain and a comatose brain side by side

Healthy brain
This MRI scan shows the normal anatomy of the cerebral hemispheres. Two types of brain tissue are visible: grey matter which performs computations (the darker tissue) and white matter (lighter fibres), which transmits signals between the various regions of this complex organ.

Brain in a coma
This scan shows irreversible destruction of the white and grey matter of the brain's frontal and cerebral regions (upper centre). Normally the white matter transmits the grey matter's computations, but here the two are almost indistinguishable, making it impossible for the organ to communicate.

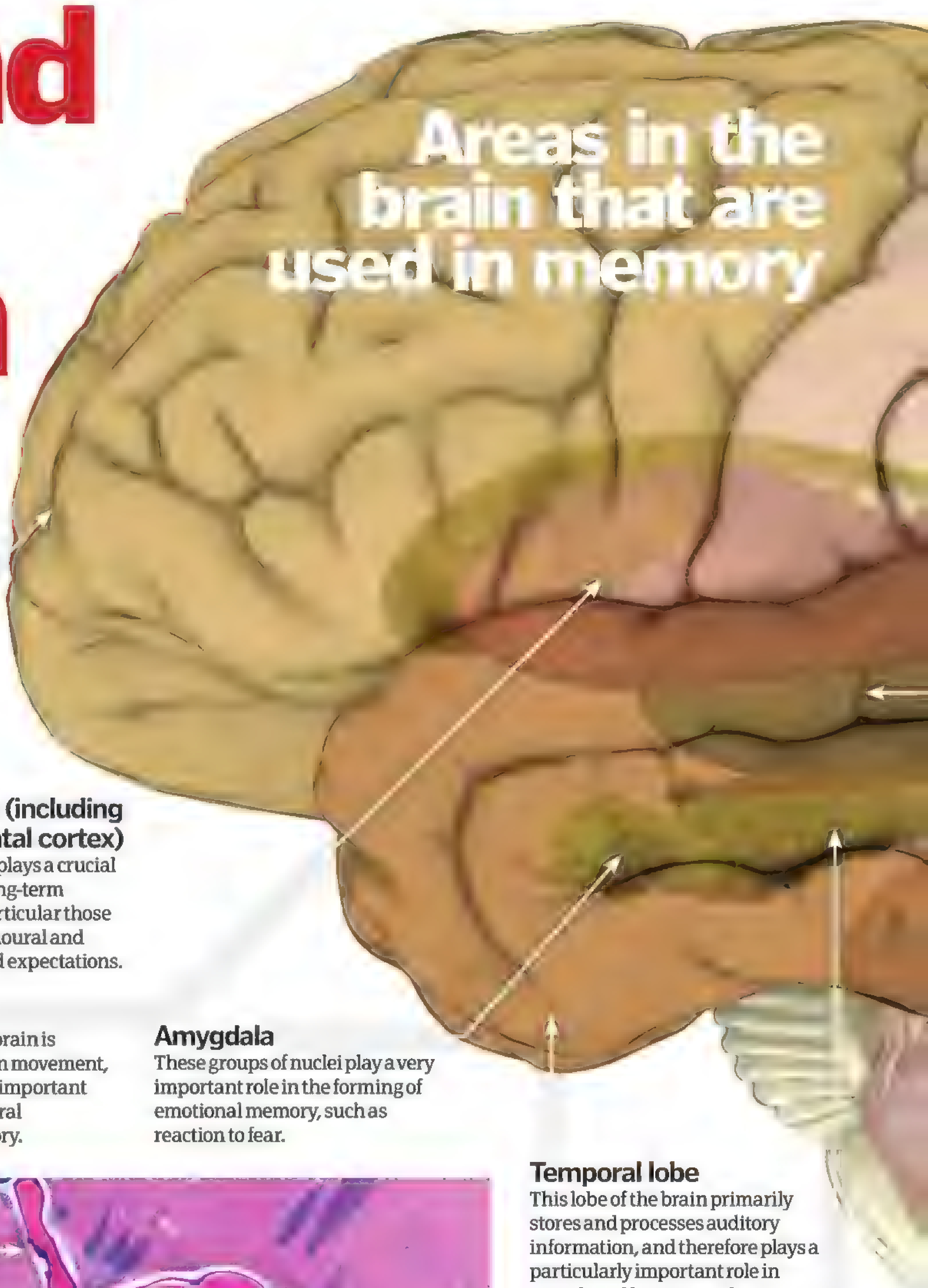
Memory and retaining information

We take it for granted, but how do we retain and utilise information from our environment?

Memory is the capacity to store and retain information, then recall it for use when needed. It is used by most organisms to operate in the most successful manner they possibly can in their unique environment. There are three main types of memory: sensory, short-term and long-term, although long-term is often split into different types of memory. Sensory memory is a very short-term type of memory, which is evoked through the senses. It lasts for a few seconds at most and is not stored. Short-term memory is a slightly longer-lasting form, sitting at around 20 secs. It's the recording of memories currently being used – ie, remembering a number to dial in the next 30 seconds. If the information is repeated, however, it causes pathways to form between neurons in the brain and a phrenological loop to be formed, causing a memory to be stored as a long-term memory. Unless this repeated firing of the neurons occurs, forced by repeating of the information, a memory will be lost.

When we cannot remember something, it's generally not because of suddenly developing a degenerating brain disease like Alzheimer's – it's far more likely to be that the correct stimuli have not been presented to prompt retrieval of the memory, or that you did not register or retain the original information properly. For example, if you cannot remember where you put your shoes when you took them off the night before, it may be that you were not paying attention when you put them down and consequently not transferred the memory from short-term to long-term in the first place, rather than having forgotten. As long as you have registered and retained the event, correct stimuli would cause a refiring of the neurons fired when creating the original memory, allowing successful retrieval of the information required. Dependent on its type, a memory is stored in different areas of the brain. This helps people to store related information more easily, as it can be linked to previously stored related material.

Areas in the brain that are used in memory



Frontal lobe (including the pre-frontal cortex)
The frontal lobe plays a crucial role in storing long-term memories, in particular those related to behavioural and social norms and expectations.

Putamen
This area of the brain is very important in movement, therefore it is an important area for procedural long-term memory.

Amygdala
These groups of nuclei play a very important role in the forming of emotional memory, such as reaction to fear.

Temporal lobe
This lobe of the brain primarily stores and processes auditory information, and therefore plays a particularly important role in speech and language. The hippocampus sits within the temporal lobe.

Hippocampus
The hippocampus is one of the crucial parts of the brain for the transferal of short-term memories into the long-term. Damage to this area will hinder an individual's ability to make new memories.

How do we form and store long-term

The time it takes for a memory to really stick

Attention — 0.2 secs
If something grabs our attention, we're far more likely to remember it. Neurons fire as we continue to focus, ensuring memory moves from short-term to long-term. The thalamus plays a big role in directing attention.

Emotion — 0.25 secs

Sensation — 0.2-0.5 secs
Sensory memory is based on receiving information from our senses – ie sight, smell, touch. The lingering feeling you have after someone touches your arm is the sensory memory fading, and this first information from the senses is the starting point for any memory.

5 TOP FACTS The brain & memories

Autistic skills
1 Individuals with autism often have skills such as fantastic mathematical ability. Some individuals such as Stephen Williams can draw entire landscapes from memory.

Sleep helps memory
2 Sleep is important to memory. Although scientists don't know exactly how it affects the brain, it has been seen that sleep aids storage and retrieval of long-term memories.

Memory and age
3 Our memory doesn't decrease very much with age. The memory loss we see in older people is generally because we tend to exercise our brains less as we age.

Complex = memorable
4 The more you have to try to work out a problem, the more likely you are to recall it. Initially your brain has to work harder, making stronger links between the active neurons.

False memories
5 People can 'remember' events that haven't happened. Often if they're led to believe something, their brain will then gather any relevant info to form a false memory.

DID YOU KNOW? Contrary to popular belief, goldfish actually have a memory of about three months – not just a few seconds

Parietal lobe
This large area of the brain plays a crucial role in bringing together sensory information. It is particularly important for the processing of visual information and spatial awareness.

Caudate nucleus
An important part of a human's memory system, this is linked to feedback processing and response and is thought to regulate activity in the cerebral cortex.

Cerebellum
This is a very important area in motor control and, to some extent, cognitive functions, including language. Damage to this area causes issues with movement, which can influence everything from balance to speaking and walking.

Thalamus
The thalamus helps to direct the brain's attention to experiences or events by sending signals to the cerebral cortex. It is important for sensation, motor skills and also helps to regulate sleep.

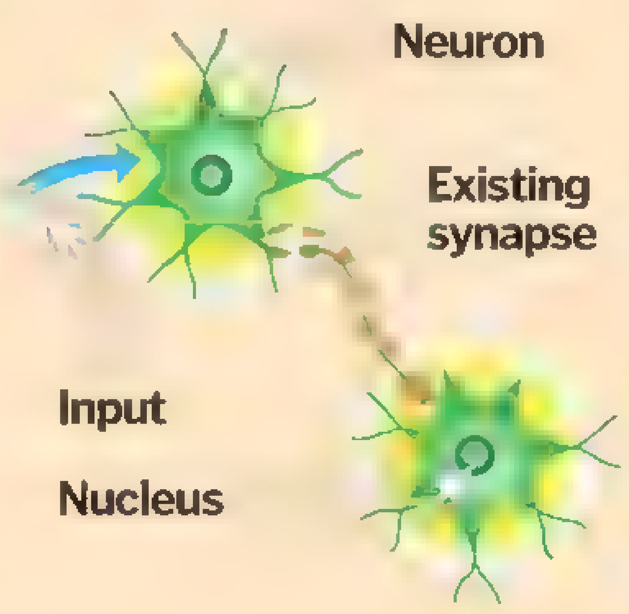
© DK Images

How do we store memories?

Memories are formed in our brains through electronic pulses passing between neurons. As neurons fire more than once, the pathway and link between the neurons strengthens; if the first neuron is triggered in the future, it is more likely that the others will too. Memories are stored in different areas of the brain, depending on what they are and what they are used for.

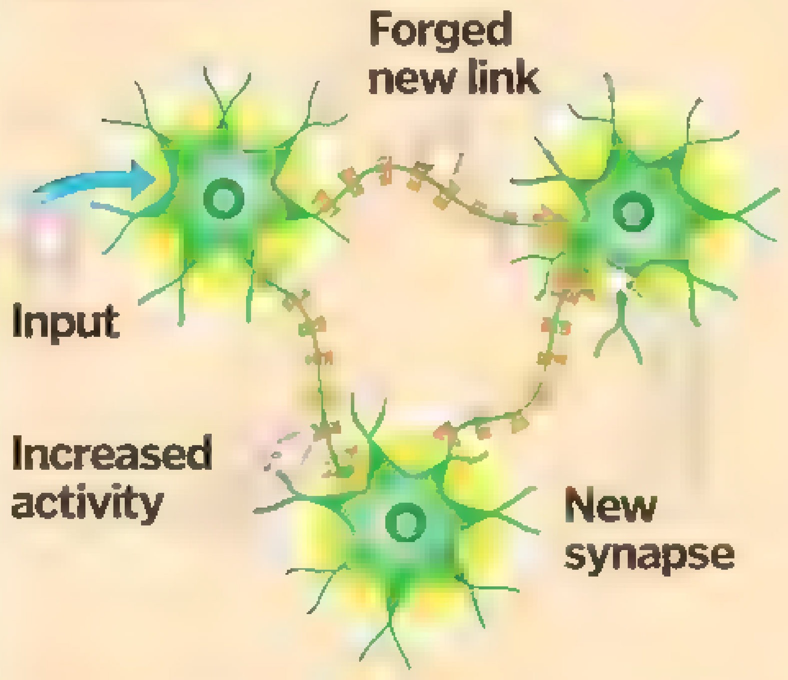
Input

The stimulus for a memory can be nearly anything. It can be related or unrelated. For example, if you see a letterbox, you may remember you had a letter to post, therefore stimulating a memory through a related input. However, some people use unrelated stimuli, like a piece of string tied to their finger, which they have formed an unrelated link to something else with.



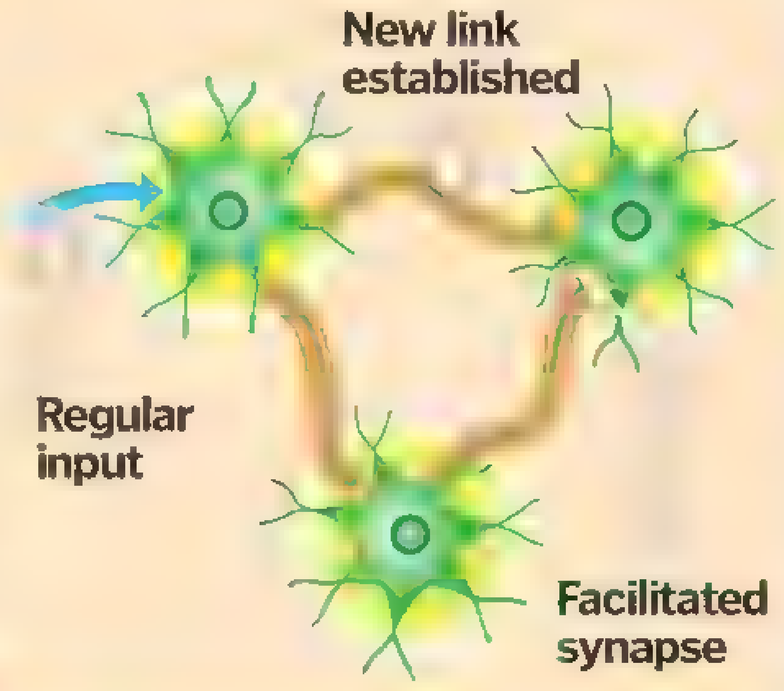
Circuit formation

As a memory is being formed, certain neurons will link together in a circuit to store this memory. It will link related memories and repetition of this circuit firing will strengthen the memory. This is called a phrenological loop.



Increasing activity

Repeated firing of the neurons involved in the first memory formation (repetition to remember) will strengthen the memory, as the neuron pathway becomes stronger and the memory can be retrieved and utilised faster.



Types of memory

The complex ways we remember…

Sensory memory

Sensory memory is evoked through the senses and is the initial perception of something. This is a fleeting memory, and will not be transferred into short- or long-term unless we focus on remembering the event.

Short-term

This type of memory is stored temporarily for up to 20 seconds. It can, however, be confused with working memory, a separate type of memory that allows an individual to retain information only for long enough to, say, complete a sum. Unless information is repeated several times to establish a pathway between neurons, it will decay and be lost.

Long-term – procedural (implicit)

This kind of long-term memory is how we remember to do things such as ride a bike. It is where we store our 'body' memories – our motor skills.

Long-term – declarative (explicit)

This type of memory is how we store facts for retrieval, and consists of things such as names and dates.

Long-term – episodic

This is where we store event-related memories and link them together. For example, if you went to a dinner party you wouldn't remember every moment, but you would recall a collection of events, smells and sounds which link together when you think of the overall event.

0.5 secs - 10 mins

Working memory

10 mins - 2 years

Hippocampal processing

If we need to retain a piece of information, or if particularly strikes us, it will travel from the short-term memory, based in the pre-frontal cortex, and travel to the hippocampus where it is processed and can move into the long-term memory.

2 years +

Consolidation

WHAT IS AVAXHOME?

“Advanced CT and MRI scans allow for 3D reconstructions and images”

Brain surgery

Discover one of the most challenging of all medical specialties. If you thought rocket scientists had to pay attention to detail, wait until you meet this lot…

There is still so much we don’t know about the human brain. However, if something goes wrong and it needs an operation, you will find yourself in need of a neurosurgeon. These guys can operate on the vast number of structures within the brain and spinal cord, and have a full arsenal of techniques and – literally – cutting-edge technologies to hand.

A neurosurgeon’s workload comes in two main forms. The emergency work is often a result of road traffic accidents or fights, and often affects young men with head injuries. These patients may have bleeding within the skull, which is exerting pressure on the brain – the neurosurgeon must relieve that pressure. There is also the planned work, where neurosurgeons try to remove tumours with meticulous detail to surrounding structures.

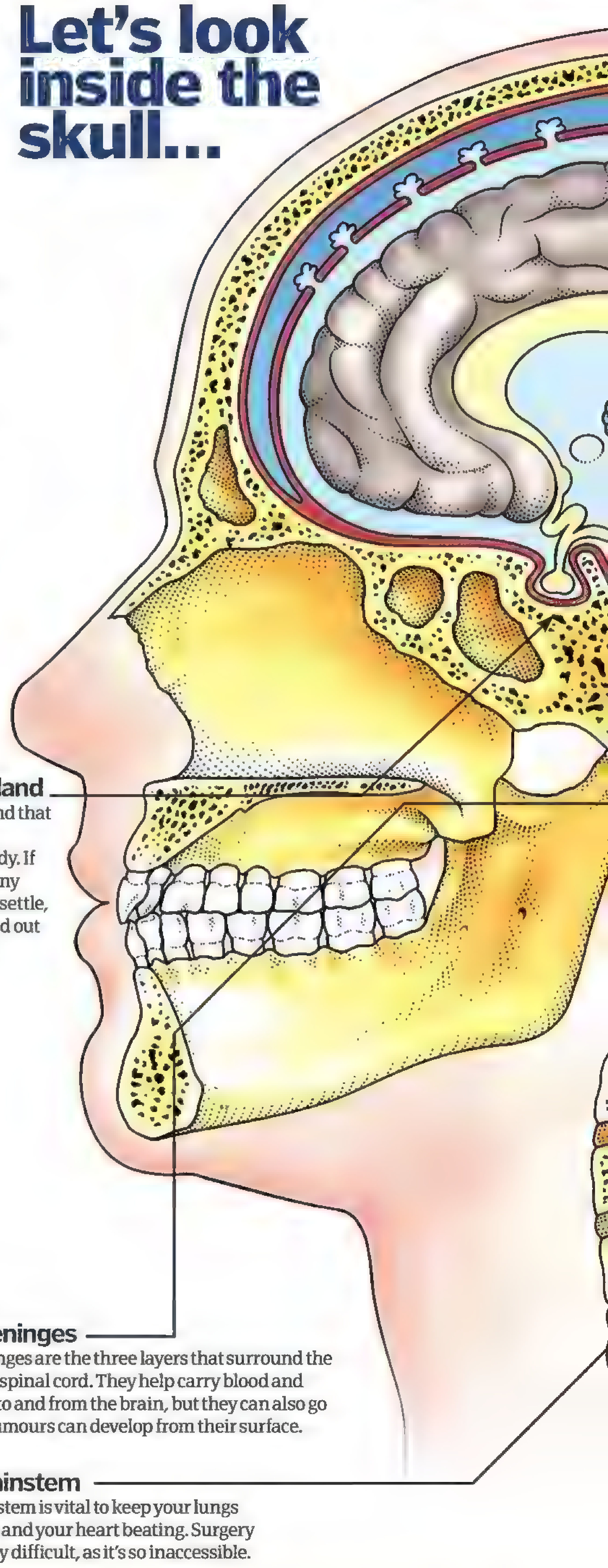
The technology starts a long way before the operation. Advanced CT and MRI scans allow for 3D reconstructions and images that we couldn’t have even dreamed of a few years ago. This allows neurosurgeons to plan the precise timing and nature of surgery – where to cut and how deep to make the incision. The imaging falls within a team approach to caring for these patients, as the team is just as important as the technology.

Surgery is becoming less invasive as time goes on. The advantages of this are smaller incisions, less disruption to surrounding tissues, less pain and shorter hospital stays. Surgeons now often use powerful microscopes with bright lights to help ▶

Famous American neurosurgeon Sanjay Gupta at work

© US Navy

Let’s look inside the skull…



The pituitary gland
The pituitary is a gland that helps regulate the hormones in your body. If it’s producing too many hormones and won’t settle, surgery can be carried out on it… via the nose.

The meninges
The meninges are the three layers that surround the brain and spinal cord. They help carry blood and nutrients to and from the brain, but they can also go wrong – tumours can develop from their surface.

The brainstem
The brainstem is vital to keep your lungs breathing and your heart beating. Surgery here is very difficult, as it’s so inaccessible.

5 TOP FACTS BRAIN SURGERY

Milky Way
1 There are around 100 billion neurones in the human brain – to illustrate just how many that is, it's about the same number of stars that exist in our galaxy!

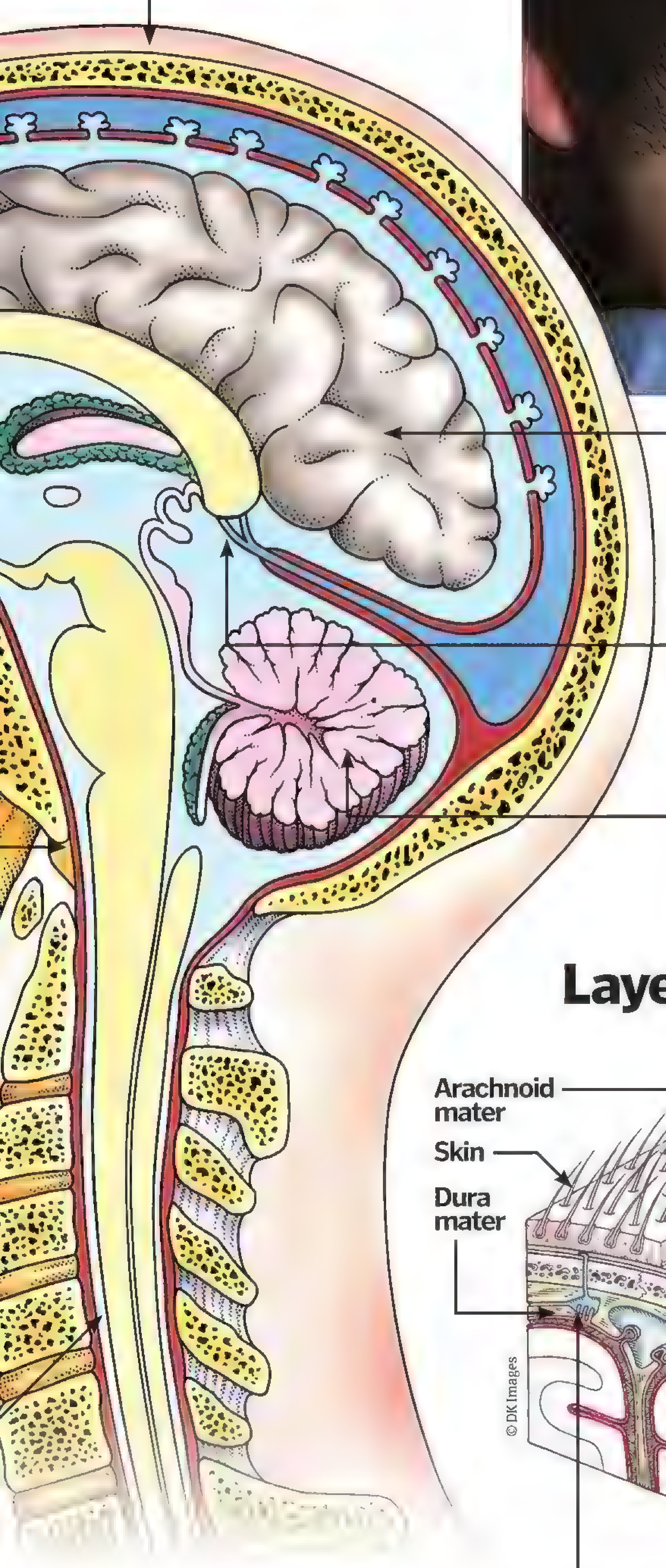
Hippocrates
2 As well as writing the Hippocratic Oath (taken by doctors to practise medicine ethically), this ancient Greek (460BC) was also an early pioneer of brain surgery.

High demand!
3 Incredibly, your brain only comprises somewhere around two per cent of your body weight. However, it uses an astonishing 20 per cent of its energy.

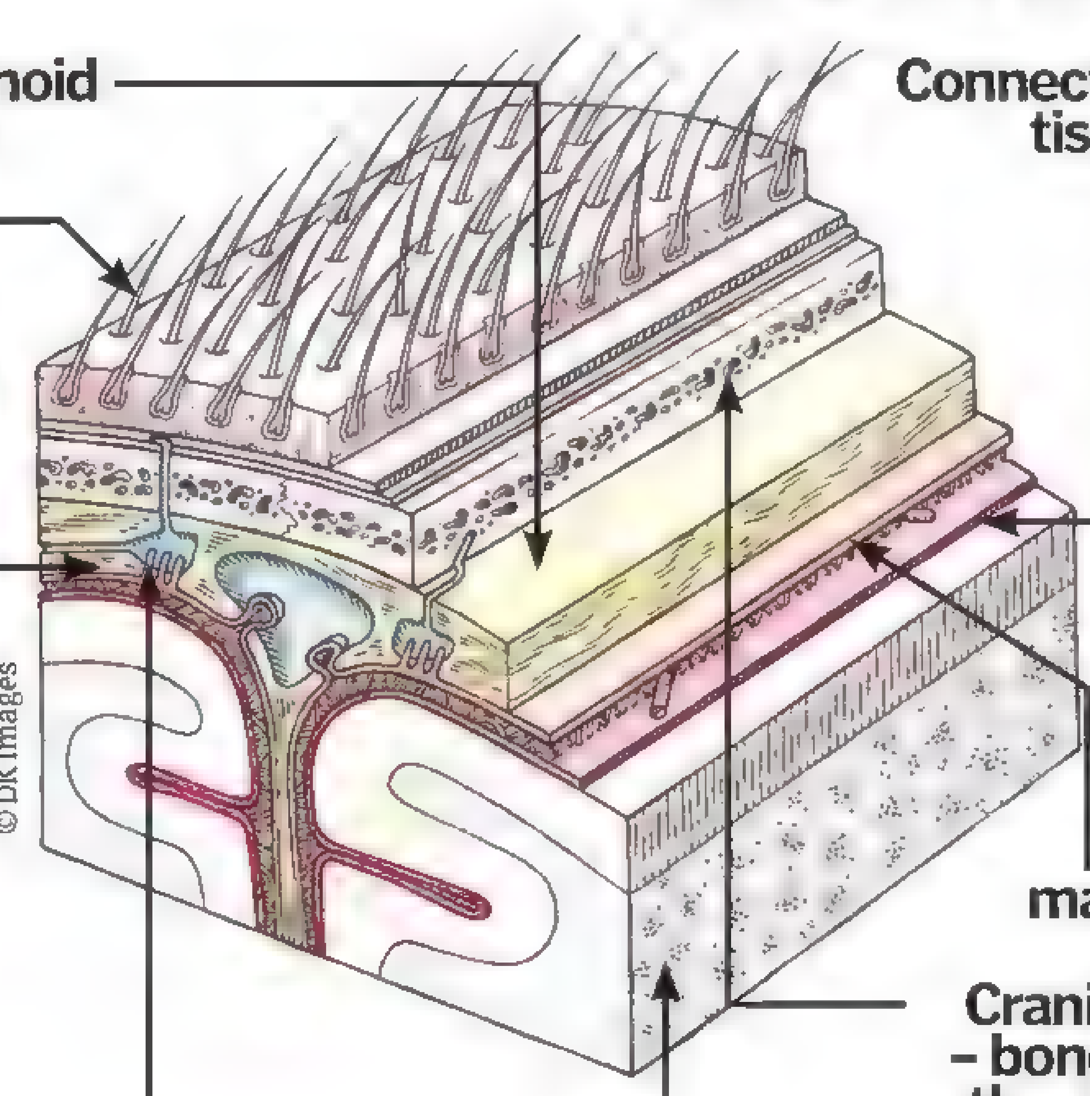
Weight
4 The adult human brain weights in region of 1,300g (2.9lb), an elephant brain, meanwhile, weighs 6,000g (13.2lb), and a cat's brain just 30g (approx 0.071lb)!

It's all in the length
5 Neurones in your brain and central nervous system range from 1mm to 1m (0.04in to 39.4in) in length. One of the longest stretches from the spinal cord to a muscle in the foot.

DID YOU KNOW? Evidence dating all the way back from 2000BC and the Stone Ages shows that people were operating on the brain



Layers surrounding the brain



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> "Advanced CT and MRI scans allow for 3D reconstructions and images that we couldn't have even dreamed of a few years ago"

Why do you need brain surgery?

Some of the common reasons for performing brain surgery

Trauma
Often following road traffic accidents or fights, head injuries are common – especially in young men. They can range from minor to life-threatening. Sometimes surgery won't help, but if the bleeding can be stopped in time, you need a neurosurgeon.
Appropriate procedure: Craniotomy
Procedure length: 1-4 hours
Recovery time: Weeks to months
Effectiveness of procedure: If early enough, completely effective. If late, it can be devastating.
Severity of condition: **Difficulty of surgery:**

Tumours
Brain tumours present themselves in a variety of ways – some people have headaches, some have co-ordination problems, and some have no symptoms at all. Metastatic tumours, where growth is from another source (such as breast or bowel), are the most common type.
Appropriate procedure: Craniotomy or stereotatic surgery
Procedure length: 2-12 hours
Recovery time: Weeks
Effectiveness of procedure: Ranges from no effects to severe effects.
Severity of condition: **Difficulty of surgery:**

Cerebral aneurysms
Swellings in the fine blood vessels within the brain can burst, leading to life-devastating bleeding. Preventing the bleeding is the trick here.
Appropriate procedure: Endovascular coiling
Procedure length: 1-3 hours
Recovery time: Days
Effectiveness of procedure: If coiled before a major bleed, it's likely to provide an excellent outcome.
Severity of condition: **Difficulty of surgery:**

Epilepsy
Surgery for epilepsy isn't for everyone. In some cases, where medicines can't control the fits, surgery may be appropriate if the fits are arising from one area.
Appropriate procedure: Temporal lobectomy
Procedure length: 2-4 hours
Recovery time: Days
Effectiveness of procedure: 95% chance of success in selected patients.
Severity of condition: **Difficulty of surgery:**

Parkinson's disease
Some patients with Parkinson's disease will benefit from some extra stimulation of their nerves. Implanting a special nerve 'pacemaker' isn't easy, but this deep brain stimulation can produce stronger signals.
Appropriate procedure: Deep brain stimulation
Procedure length: 2-4 hours
Recovery time: Days
Effectiveness of procedure: Medium to good.
Severity of condition: **Difficulty of surgery:**

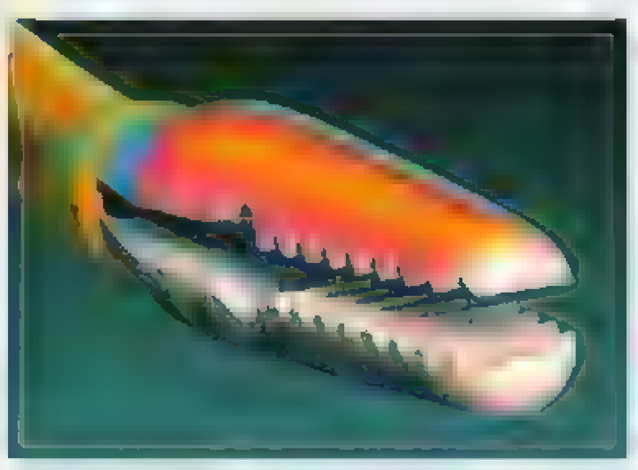
The right tools for the job...

Discover the equipment used by brain surgeons

© Marvin 101 2009

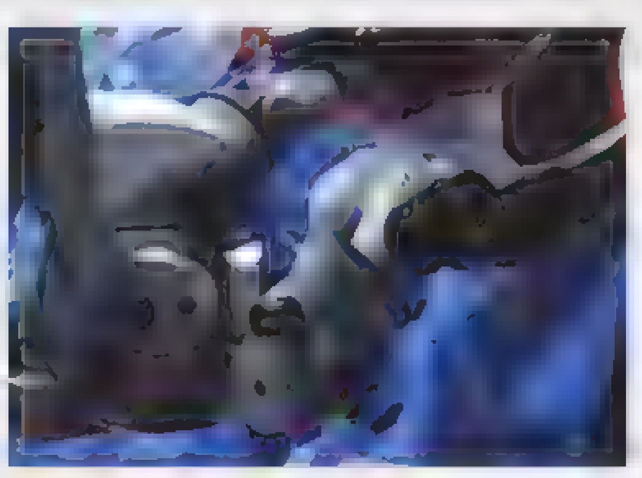
Guglielmi detachable coil

These platinum wires are fed into small aneurysms (enlarged arteries) within the brain via an artery in the groin. Once coiled up inside the aneurysm sac, they stop blood flow and thus prevent bleeding.



Surgical microclamps

These small clamps can be used to grab tumours to help the surgeon dissect them away from surrounding structures.



High-performance microscope

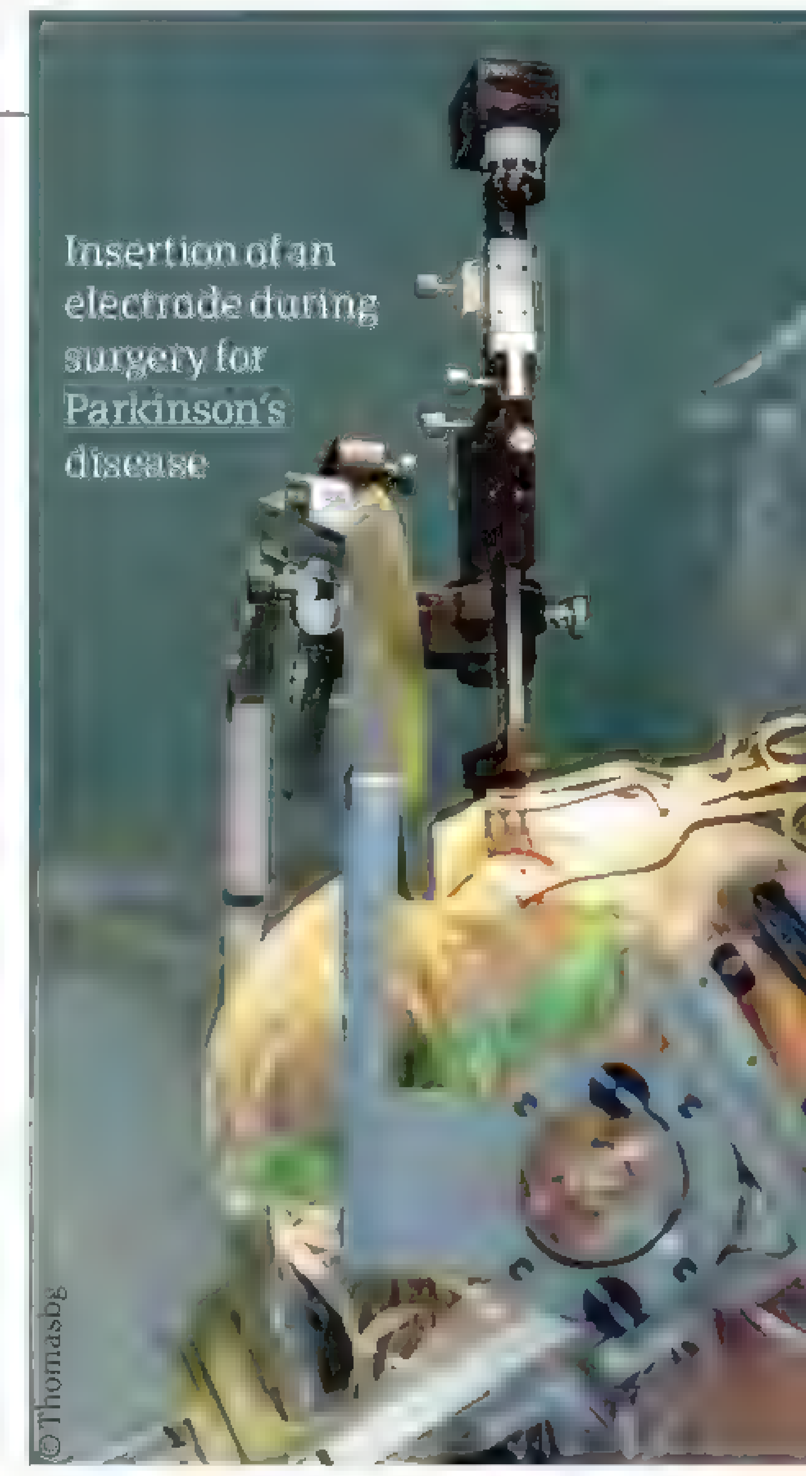
These powerful microscopes with bright lights enable surgeons to operate through tiny incisions or keyholes, which prevents damage to those important surrounding structures.

them remain as precise as possible. These microscopic techniques require a huge amount of skill, dexterity and hand-eye co-ordination that would impress even a fighter pilot.

New neuro-navigation techniques and robotic surgery can help surgeons get to the hard-to-access places, which previously would have been inaccessible. Special scanning cameras and computers are used during the operation and are matched to a pre-existing scan to guide the surgeon's hand – much like the satellite navigation systems used by drivers. Neuro-endoscopy, which involves the use of tiny cameras to access the brain, is opening up many new opportunities in brain surgery. Incredibly, it's possible to access the brain via a tiny cut in the back of the nose, too.

The brain is the network hub of the human body, co-ordinating all of the sensations we feel and then providing instructions for the complex movements we perform. Although it receives all of the pain signals from the body, the brain itself doesn't have pain receptors. This means that there is potential for neurosurgery to be carried out with the patient awake. However, there are pain receptors in the skin, muscles and linings that surround the brain, so it certainly isn't for everyone and it isn't performed everywhere.

Incredibly, there are bits of your brain that you can survive without – and you might not even notice any difference. It really depends on which part of the brain is removed – remove even a small part of the brain stem, for example, and you'll die instantly. Removing or cutting larger parts of the main brain can leave just a few effects, such as memory problems. However, these discoveries were often made at the peril of surgeons operating and experimenting on patients in years gone by, which are now lessons confined to the history books.

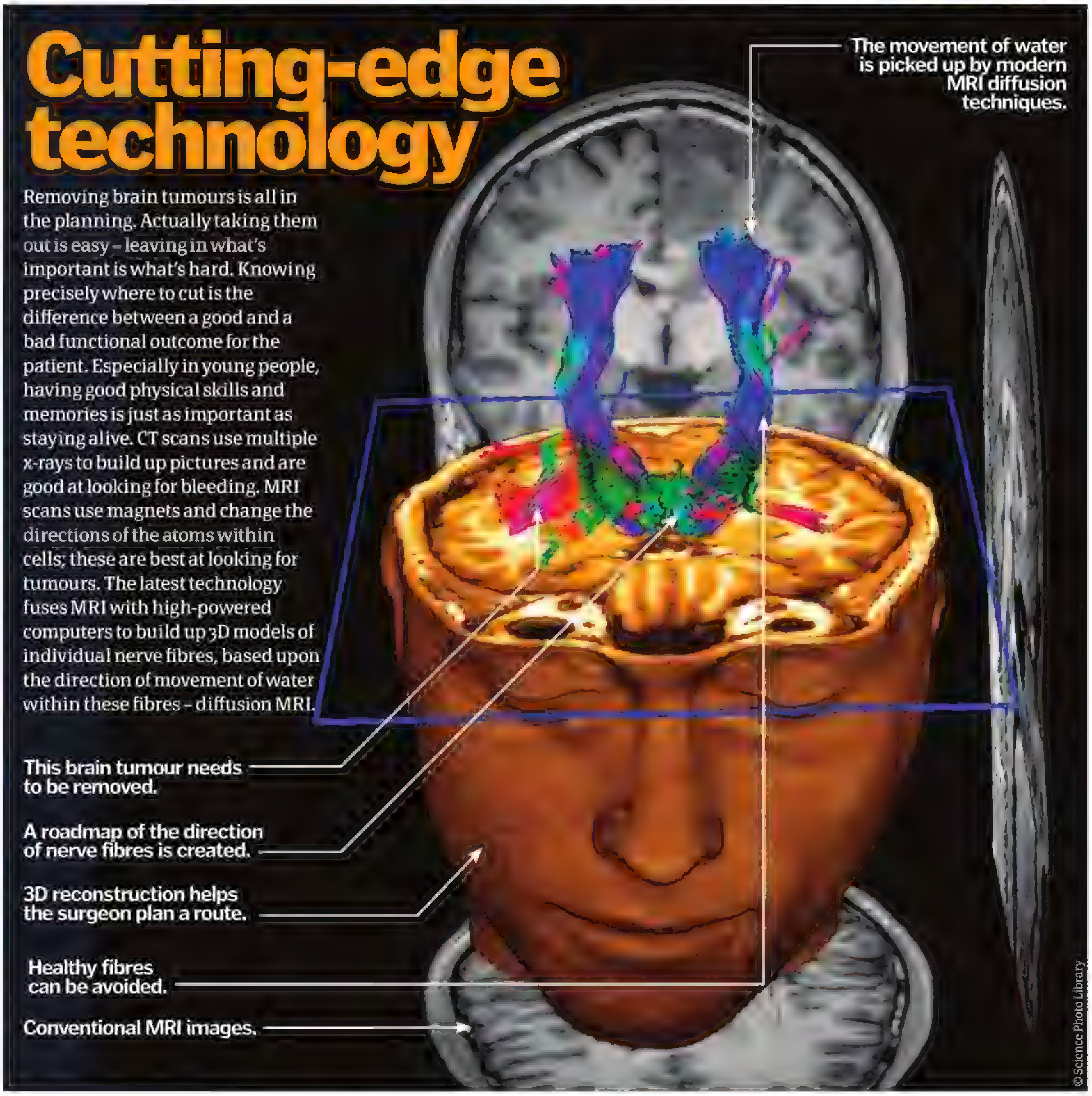


Insertion of an electrode during surgery for Parkinson's disease

© Thomasbg

Cutting-edge technology

Removing brain tumours is all in the planning. Actually taking them out is easy – leaving in what's important is what's hard. Knowing precisely where to cut is the difference between a good and a bad functional outcome for the patient. Especially in young people, having good physical skills and memories is just as important as staying alive. CT scans use multiple x-rays to build up pictures and are good at looking for bleeding. MRI scans use magnets and change the directions of the atoms within cells; these are best at looking for tumours. The latest technology fuses MRI with high-powered computers to build up 3D models of individual nerve fibres, based upon the direction of movement of water within these fibres – diffusion MRI.



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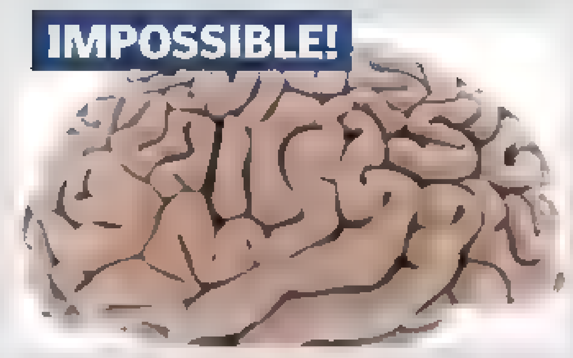
COMPLICATED

1. Scarless surgery
Doctors can focus ultrasound or gamma rays onto a tumour to obliterate it, preventing the need for surgery in some patients.

MORE COMPLICATED

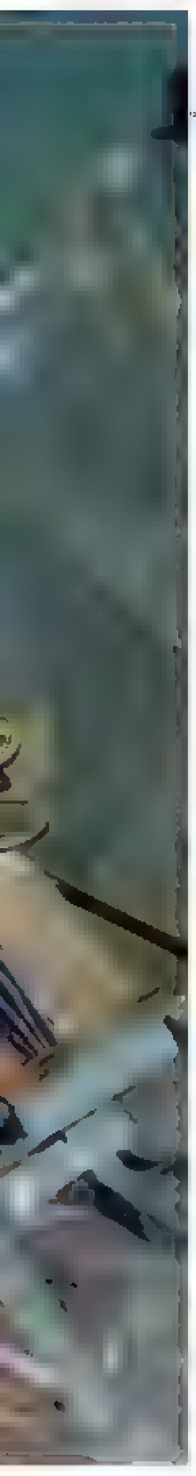
2. Bones
In *Star Trek IV: The Voyage Home*, Bones repairs an artery in Chekov's head by using only his medical tricorder. Some people think this may become reality!



IMPOSSIBLE!

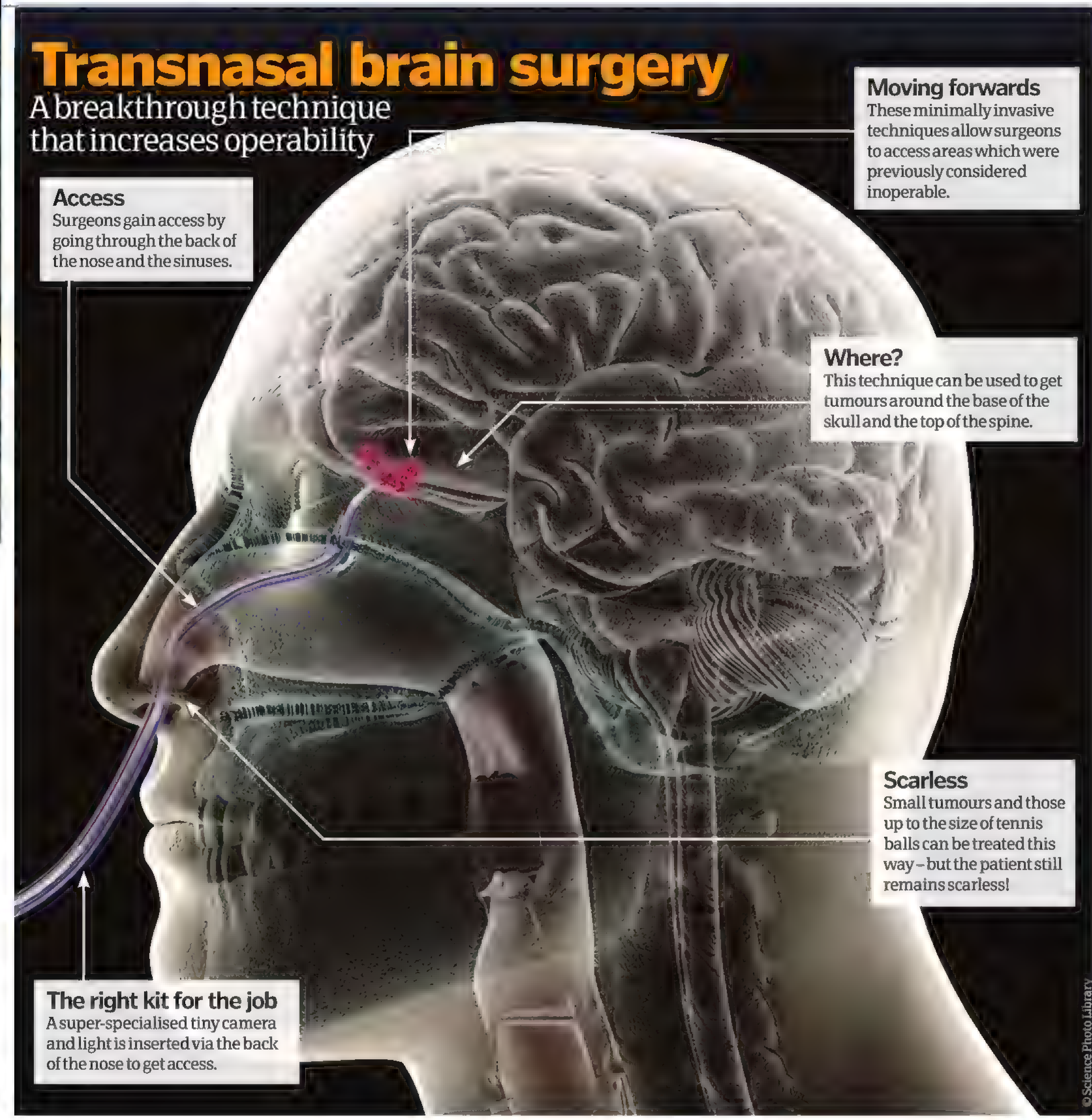
3. Brain transplant
Scientists are experimenting with transplanting animals' brains into other animals, though it raises ethical issues.

DID YOU KNOW? Parkinson's patients can have tiny stem cells transplanted into their brains to stimulate new neurone growth



Transnasal brain surgery

A breakthrough technique that increases operability



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Time critical!

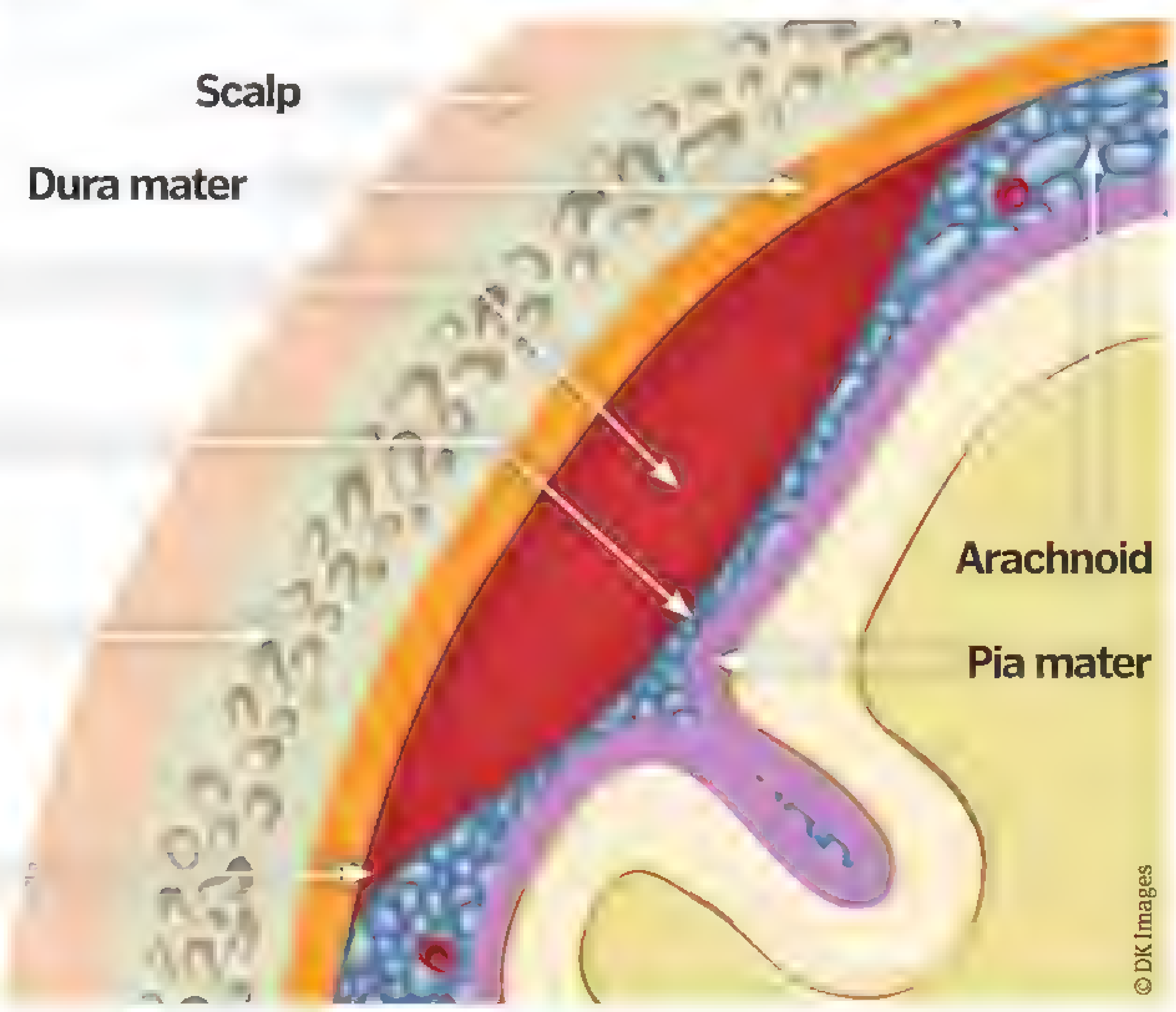
A haemorrhage needs urgent attention to save a life

Clot
A blood vessel has broken, forming a clot (haematoma).

Under pressure
The clot is causing increased pressure within the skull, squeezing the brain.

Skull
Since the skull is rigid, the brain is forced downwards towards the only exit – into the spinal column. This rapidly leads to death unless treated, as it damages the vital brainstem.

Life-saving
In true life-saving surgery, a surgeon will cut away a small piece of skull (craniotomy), clear away the clot and stop the bleeding.



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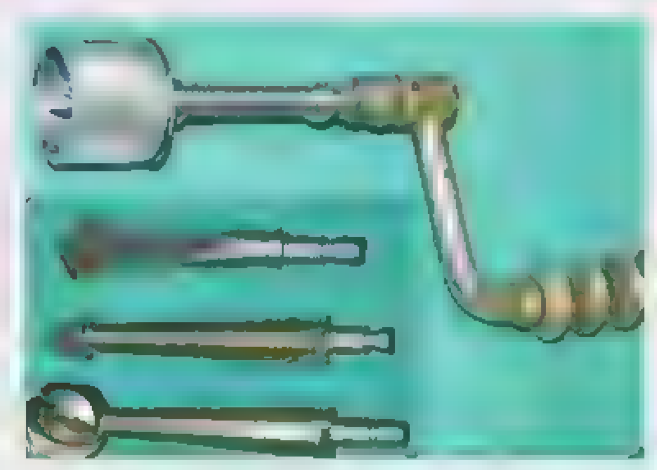
The right tools for the job...

Discover the equipment used by brain surgeons

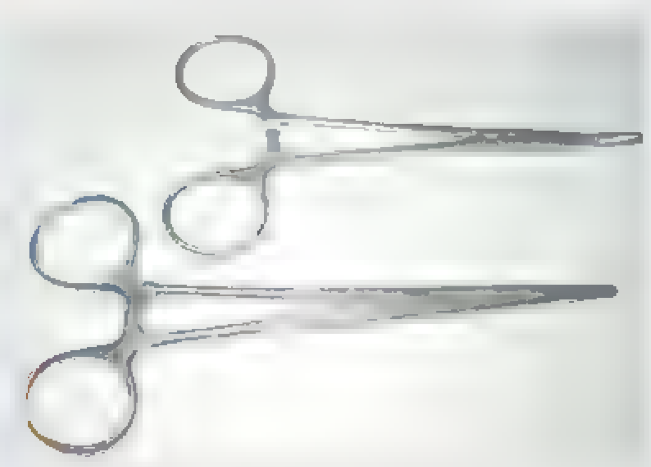
Navigation systems

This computer system merges pre-operative CT and MRI scans with intra-operative information gathered from lasers and infrared. The result is a 'map', which surgeons use to navigate to difficult-to-find tumours.



Burr-hole drill

Although not used much any more in the Western world, a drill is used to evacuate blood clots which form around the brain following accidents. They are still used in some parts of the world.



Haemostat

A vital surgical tool, a haemostat is a scissor-shaped device used to control bleeding. They are locked in place via a series of interlocking teeth, which can be varied according to the amount of pressure needed.

How brains can control prostheses

Learn how scientists are using the mind to manipulate life-changing technology

A patient performs functional tests with DARPA's Proto 1 arm

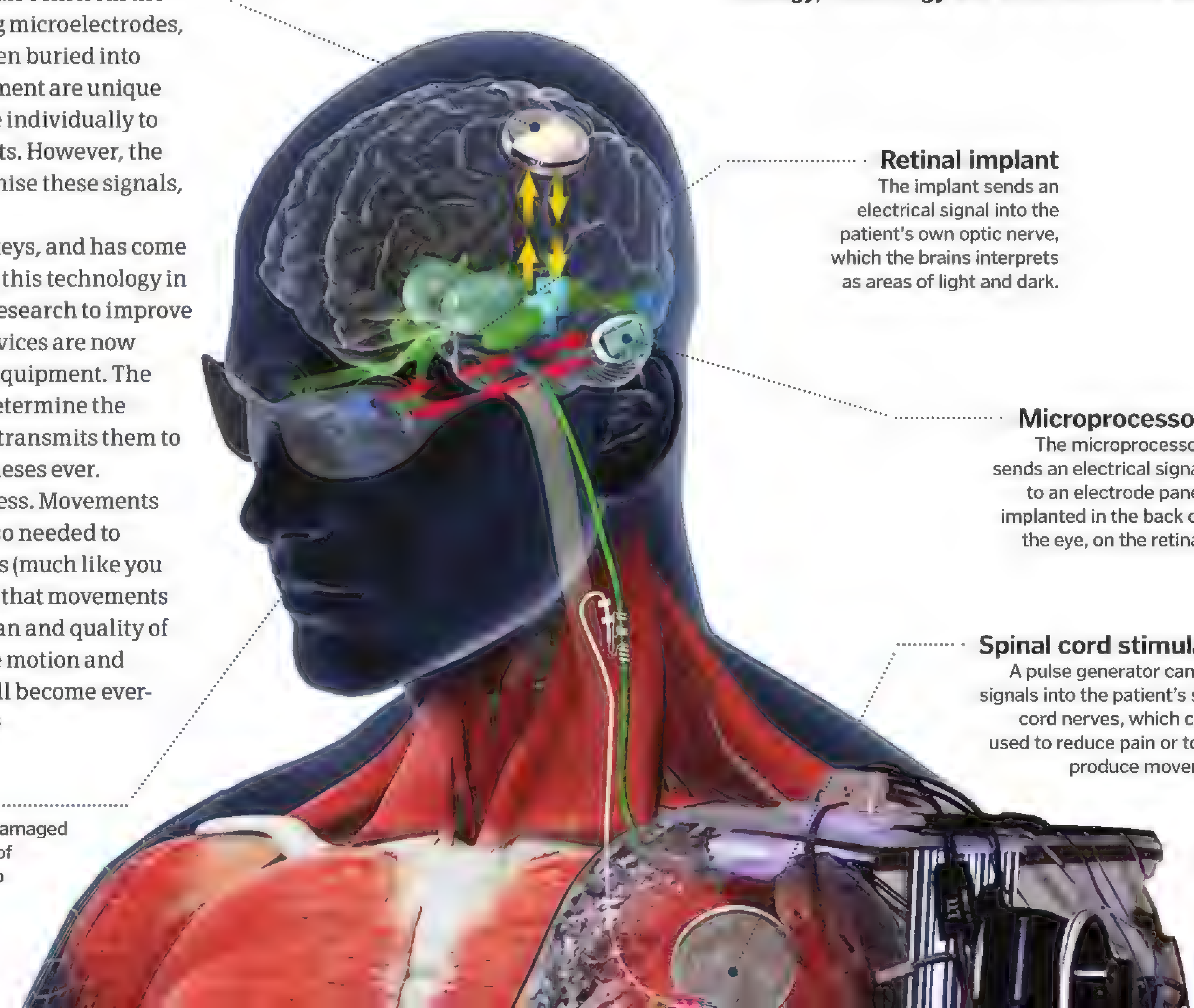
Scientists are exploiting ways to connect the human brain to modern prostheses (such as artificial limbs) or via computers to expand our functionality. It's hoped patients will be the ones to benefit, particularly those who have lost limbs in accidents or at war. Motor prostheses interpret the natural signals sent from the brain. The electrical signals sent are detected using microelectrodes, which can be implanted underneath the skin or even buried into nerves. The brain signals for each particular movement are unique and slightly different, and the aim is to detect these individually to allow patients the ability to perform fine movements. However, the science is still developing to more accurately recognise these signals, and the perfect prosthesis does not yet exist.

The initial technology was developed with monkeys, and has come a long way since. There has been a massive push in this technology in recent years, as military funding starts to finance research to improve injured soldiers' quality of life. The initial crude devices are now being replaced with technologically cutting-edge equipment. The most modern devices use hundreds of sensors to determine the precise movements the brain is commanding, and transmits them to some of the most complex and sophisticated prostheses ever.

That said, this technology is still a work-in-progress. Movements are still limited and require refinement. Work is also needed to improve feedback to the patient from the prosthesis (much like you can feel what you're touching with your fingers), so that movements can become even more realistic. As both the life span and quality of the microprocessors improve, the motion and functionality of prostheses will become ever-more reliable and lifelike.

Where modern prostheses can make a difference

The latest prostheses are a combination of biology, technology and state-of-the-art design



Brain signals
Microprocessors to control movement of the limbs can be implanted near the brain to detect early signals.

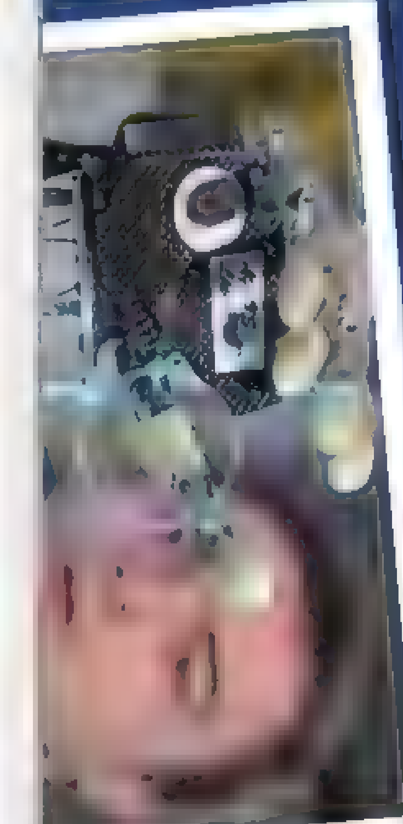
Retinal implant
The implant sends an electrical signal into the patient's own optic nerve, which the brains interprets as areas of light and dark.

Microprocessor
The microprocessor sends an electrical signal to an electrode panel implanted in the back of the eye, on the retina.

Spinal cord stimulator
A pulse generator can send signals into the patient's spinal cord nerves, which can be used to reduce pain or to help produce movement.

Bionic eye
For patients who have a damaged retina, a camera in a pair of glasses sends an image to the microprocessor.

"The initial crude devices are now being replaced with technologically cutting-edge equipment"



DID YOU KNOW? Upper limb tech is far harder to perfect than lower limb tech, as it demands much finer movements

Modern bioprostheses
These are combinations of modern computing and engineering technology to produce as lightweight yet realistically functional movements as possible.

Fine movements
Developing fine movements of the fingers is one of the ultimate aims of this field, as it will allow patients to write, feed themselves and perform other everyday tasks we take for granted.

Myoelectric prostheses

This cutting-edge prosthesis combines the best possible function with a pleasing aesthetic finish. Rather than using cables and pulleys like older prostheses, this uses batteries and microprocessors to interpret the brain's electrical activity. The main disadvantages are its current weight and expense, although both are coming down rapidly.

History of prostheses

A look at some of the most game-changing developments in the world of prosthetics

1957
First cochlear implant
The first cochlear implant converts sound waves into strong electrical impulses and still brings improved hearing to many people around the globe.

1990s
CAT-CAM
The widespread introduction of the modern fitting limb prosthesis – the contoured adducted trochanteric-controlled alignment method (CAT-CAM) – paves the way for the development of today's sophisticated prostheses.

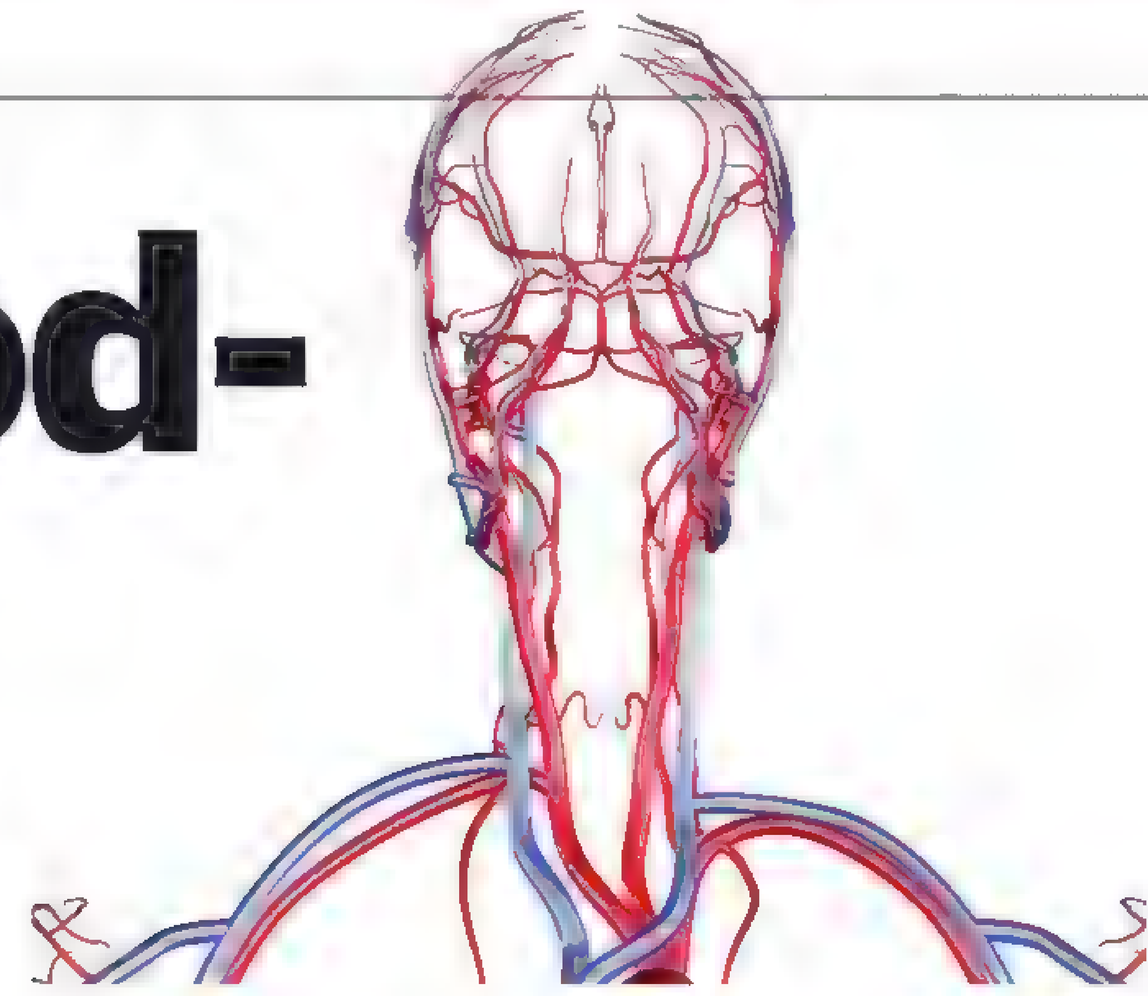
2002
Median nerve cybernetics
A microelectrode array is implanted into a healthy volunteer's median nerve located in the arm, which enables him to control hand functions.

2008
Monkeys
Two monkeys learn to feed themselves marshmallows using a robotic arm controlled by a computer that's linked to their brains.

2009
Modular prosthetic limb
Developed by the USA's Defense Advanced Research Projects Agency (DARPA), this prosthesis offers 22 degrees of motion with independent movement of each finger. The Proto prosthesis is still being developed to this day.

"The tight junction between cells regulate the size and type of particle that pass between them"

What is the blood-brain barrier?



How does this gateway control the molecules that pass from the blood into the brain

The blood-brain barrier (BBB) is an essential group of cells that line the blood vessels in the central nervous system (brain and spinal cord). They allow passage of materials between the clear fluid surrounding the brain (cerebrospinal fluid) and the red blood cells in arteries, veins and capillaries. The key advantage of having such a barrier is that it prevents large micro-organisms passing into the brain and causing infections. While infections in other areas are common (such as after a cut finger, or mild chest infections), those affecting the brain are much rarer. However when they do occur (eg meningitis), they are potentially life threatening as they are very difficult to treat.

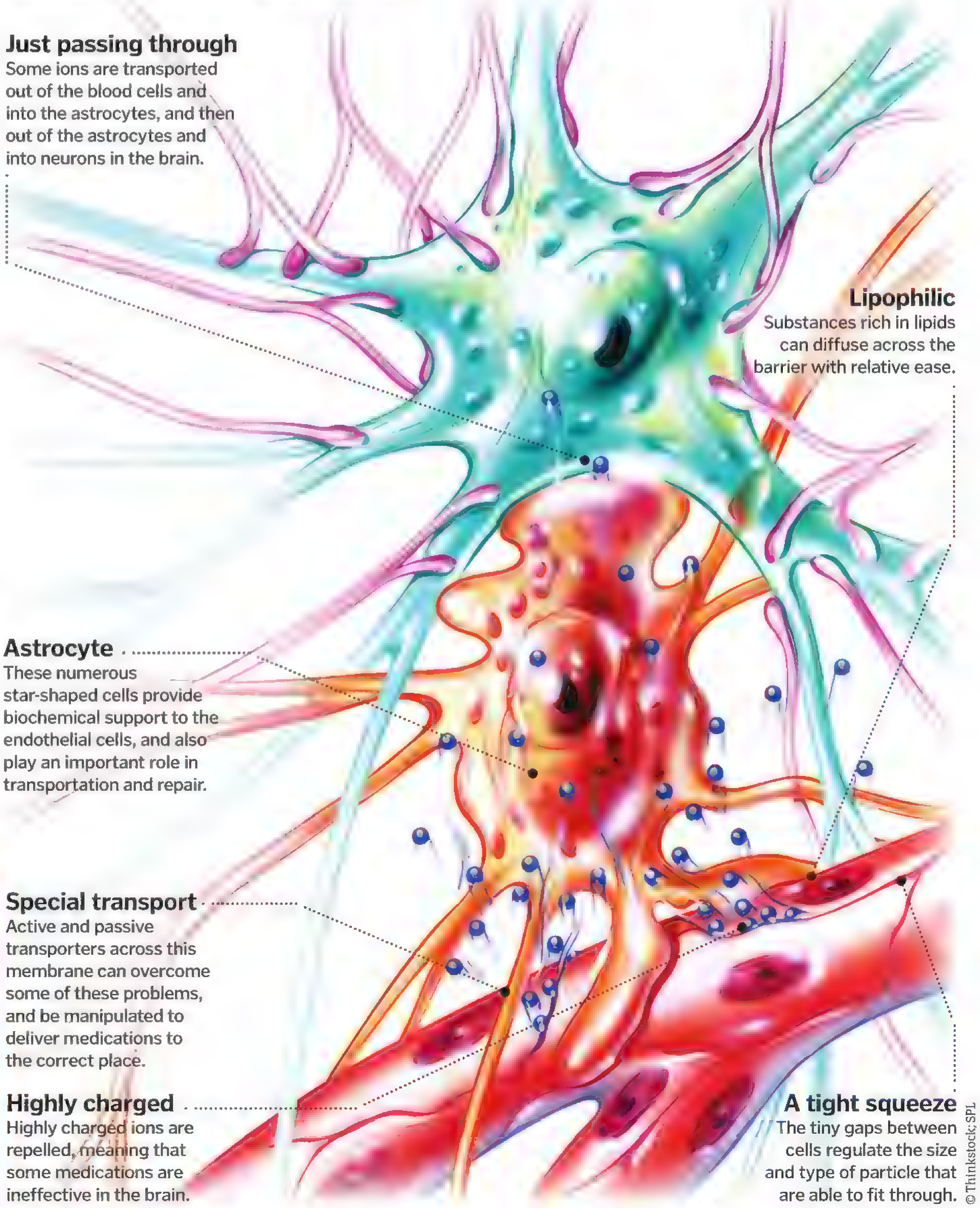
The tight junctions between cells regulate the size and type of particle that pass between them, including oxygen molecules, carbon dioxide molecules, nutrients and hormones. Since it's so effective, it also stops medications from entering the brain (such as certain antibiotics), so while they are effective in the rest of the body, they are ineffective in this vital organ. Overcoming this is a major aim of doctors in the next decade, and the battle has already started. Manipulating the blood-brain barrier's natural transport mechanisms and delivering drugs within nanoparticles to squeeze through the tight junctions are just two examples of the modern techniques that are under development.

Crossing the BBB

The endothelial lining of the blood-brain barrier loves lipids (fatty molecules), but it hates particles with high electrical charges (ions) and large substances. Thus the ideal substance is small, rich in lipids and has a low electrical charge. Barbiturates are such an example, as they freely flow across the blood-brain barrier to suppress brain function; they act as sedatives and antidepressants. However this free movement comes with risks – too much of it will accumulate and slow the brain to a point where you can lose consciousness and even stop breathing.

Breaking down the barrier

This built-in gateway is the main line of defence for the central nervous system



DID YOU KNOW? *Deep relaxation isn't necessary for hypnosis to work; participants can even be hypnotised while on a treadmill!*

Hypnosis explained

Supernatural mind control, placebo effect or something in between? Hypnosis takes us on a journey into the mind…

In its simplest terms, hypnosis is a process by which someone becomes less aware of conscious thought and inhibition, and more open to suggestion. Changes in the brain's neural activity can alter the subject's perceptions and emotions, enabling them to focus their thoughts and filter out distractions. One key area involved in such altered states includes the frontal lobe, which accounts for a large portion of the brain's mass and is responsible for a person's personality, emotions and long-term memory. Changing the brain's frontal lobe function in turn alters a person's subjective experience of reality, cognitive processes shift and elective actions occur without conscious volition.

Other areas of the brain that are involved with altered states include: the parietal lobe, which can distort the subject's perception of space and time; the thalamus, which can induce the feeling in a subject that they're 'in a world of their own'; and the reticular formation, which receives sensory information from the outside world and determines what is important and what's not, so as to prevent us from suffering sensory overload.

Typically a hypnotist will 'induce' the subject into a highly suggestible state, via techniques such as progressive relaxation or surprise – however, a formal induction isn't a prerequisite for hypnotism to succeed.

Clinical hypnosis is conducted to address both psychological and physical problems. For example, it has been used to reduce the experience of pain in severe burn victims and of women in labour, and offer relief from nausea to patients undergoing chemotherapy. Hypnosis is also used to treat those with anxiety and various phobias as well as to modify behaviour in the treatment of eating disorders and smoking cessation.

Hypnotism is a form of dissociation that works by allowing the patient to respond to suggestion while ignoring competing or incompatible stimuli. This is achieved by means of existing mental faculties. People who are hypnotised have the same physical and mental abilities that they possess in a normal state. They cannot be empowered to perform acts of superhuman strength, nor can they be forced to recall events that they never retained, such as memories of their infancy.

Who can be hypnotised?

The ability to be hypnotised falls along a normal distribution, or bell-shaped curve, with the majority of people being moderately responsive to hypnotic suggestion, and smaller numbers at the extremes, either very difficult or very easy to hypnotise. Hypnotisability – much the same as IQ – is a relatively stable quality that will remain consistent throughout adulthood.

Scientists are always searching for characteristics that will predict successful hypnotism. They have ruled out any association between hypnotisability and being 'weak willed' or gullible. Nor are people with dissociative qualities or excellent imaginations especially open to this practice. However, it does appear that people who have the ability to become completely engrossed in daydreams or music are more likely to respond to hypnosis than those who cannot.

The human brain is capable of entering an altered consciousness whereby the subject undergoes a range of conscious experiences

The state debate

One controversy surrounding hypnosis is the state debate. While professionals on both sides of the argument agree that hypnosis exists, they disagree about the way it takes place.

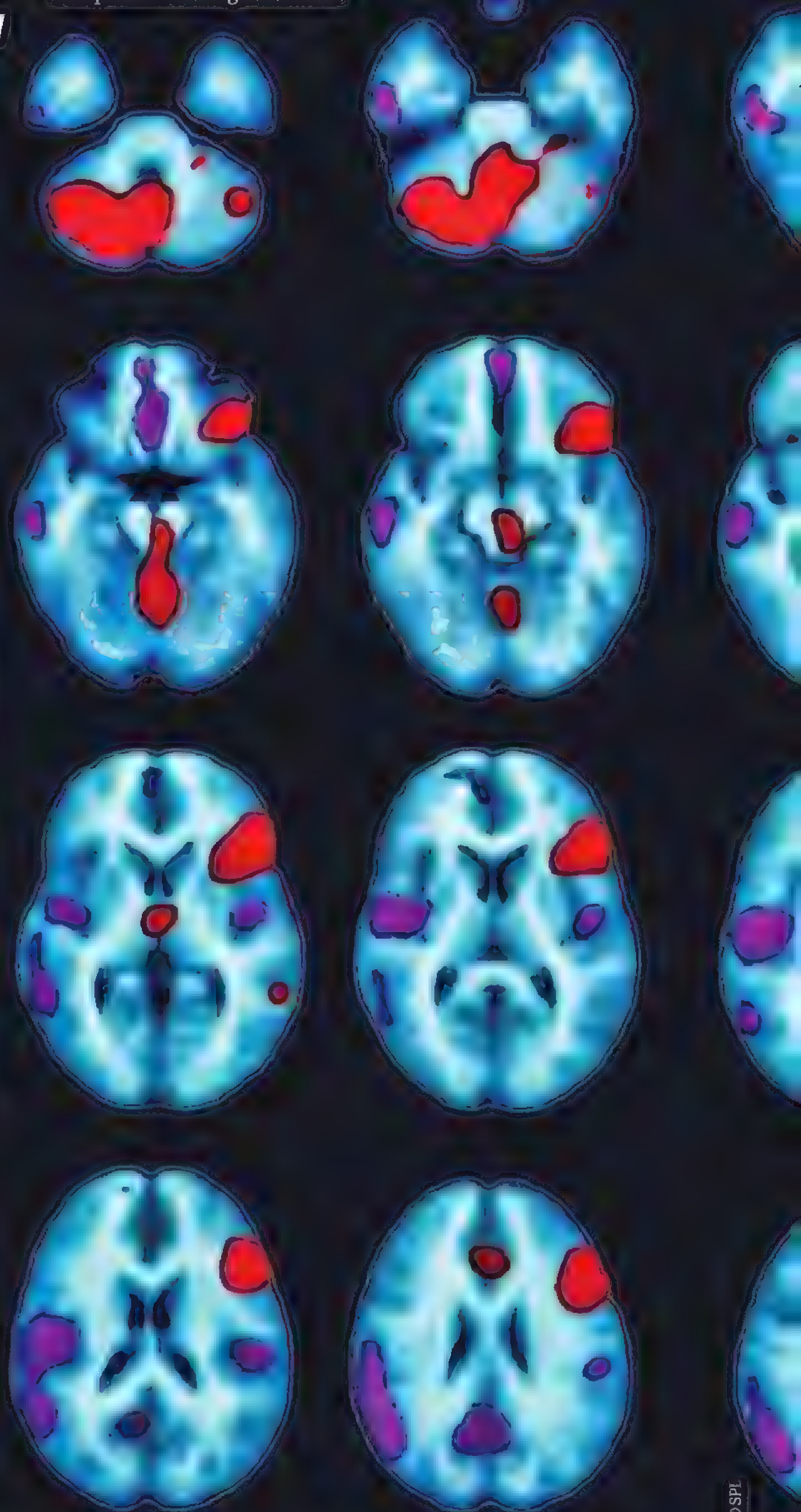
Subscribers to the state theory believe that hypnotic induction puts participants into an altered state of consciousness, which is totally discrete from normal waking reality. State theorists argue that it is this shift of state which allows for the atypical behaviour that's often observed during hypnosis.

Non-state theorists, on the other hand, maintain that the process of hypnosis moves participants along a continuum into a zone of heightened suggestibility, perhaps due to expectations or compliance, but that the mechanisms employed during hypnosis are the same as those governing normal waking experience.

"Scientists have begun to ascertain which parts of the brain function as we form different thoughts"

IS IT POSSIBLE TO SEE OUR THOUGHTS?

This CT scan of the brain has fused PET images over it, showing activity of different regions when the patient is exposed to a range of stimuli



© SPL

The brain is perhaps the most vital of the body's vital organs, yet in many ways it's also the least understood

At its most simple level, the brain is a series of interconnecting neurons that relay electrical signals between one another. They are 'all or none' transmitters as, like a computer, they either transmit a signal (like a binary '1') or do not ('0'). Different neurons are receptive to different stimuli, such as light, touch and pain. The complex activity of these neurons is then interpreted by various parts of the brain into useful information. For example, light images from the eye are relayed via the optic nerve to the occipital cortex located in the back of the skull, for interpretation of the scene in front of you.

The generation and interpretation of thoughts is a more complex and less well understood process. In fact, it is a science of its own, where there are many definitions of what a 'thought' is, and of what defines consciousness. In an effort to better define these, doctors, scientists and psychologists have turned to novel imaging techniques to better understand the function of our minds. Research into understanding brain activity and function has led to some of the most advanced imaging techniques available. This has helped to treat conditions such as Alzheimer's dementia, epilepsy and stroke, as well as mental illnesses where there is not necessarily a physical problem within the brain. It has also led to benefits for imaging other diseases in other parts of the body, including several forms of cancer.

© SPL

This DTI view of the brain uses the high water content in neurons to show fine structure and activity

These advanced imaging techniques include scans to produce images of the anatomical structure of the brain, and interpretation of energy patterns to determine activity or abnormalities. Scientists have started to ascertain which parts of the brain function as we form different thoughts and experience different emotions. This means we are very much on the brink of seeing our own thoughts.

How can we view the brain?

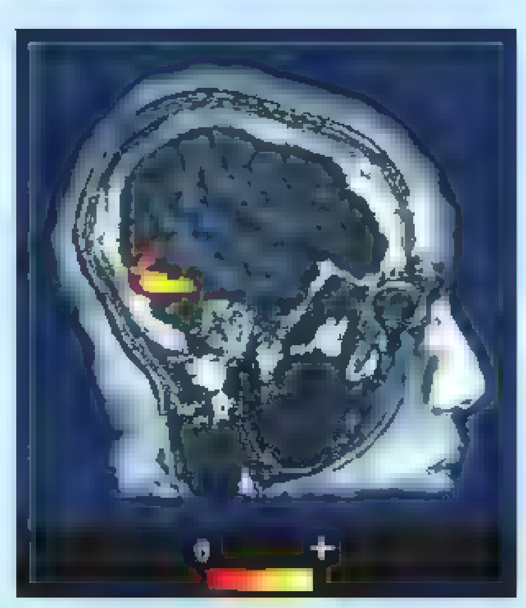
Computed tomography (CT)

This combines multiple X-rays to see the bones of the skull and soft tissue of the brain. It's the most common scan used after trauma, to detect injuries to blood vessels and swelling. However, it can only give a snapshot of the structure so can't capture our thoughts.

© Oliver Sh...

Magnetic resonance imaging (MRI)

MRI uses strong magnetic fields to align the protons in water molecules in various body parts. When used in the brain, it allows intricate anatomical detail to be visualised. It has formed the basis of novel techniques to visualise thought processes.



Functional MRI (fMRI)

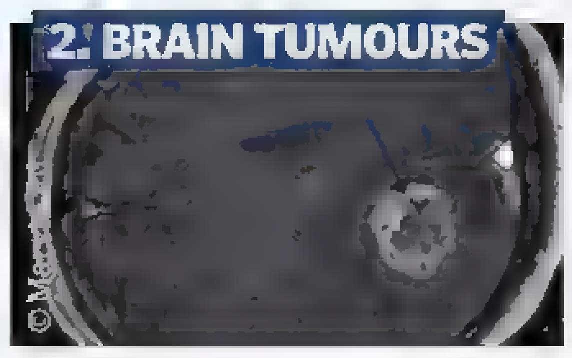
This form of MRI uses blood-oxygen-level-dependent (BOLD) contrast, followed by a strong magnetic field, to detect tiny changes in oxygen-rich and oxygen-poor blood. By showing pictures to invoke certain emotions, fMRI can reveal which areas are active during particular thoughts.

1. HEAD TRAUMA

© Thierry Geoffroy

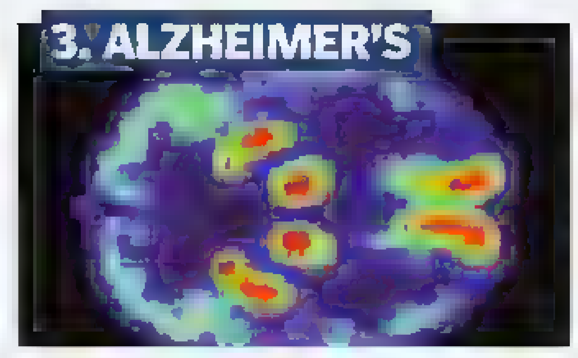
CT scan
Fast and easily accessible 24 hours a day, these scans can identify life-threatening bleeding within the skull for neurosurgeons to stop.

2. BRAIN TUMOURS



3D MRI
These 3D scans show intricate anatomical details of brain tumours, particularly in relation to the surrounding structures. This enables doctors to determine if they can be safely removed or not.

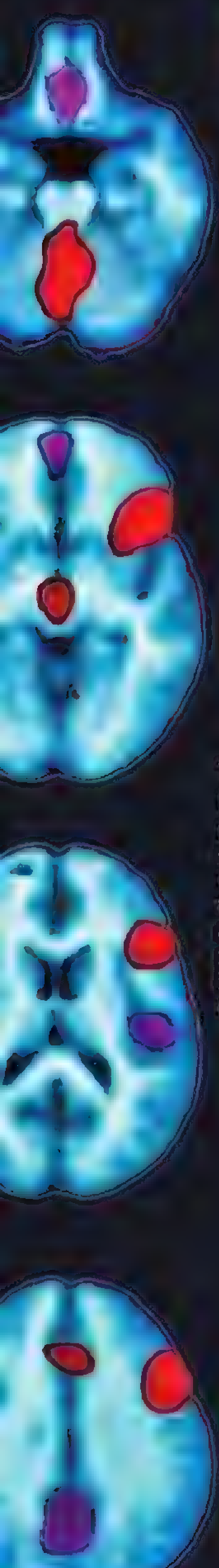
3. ALZHEIMER'S



PET scan
This functional imaging is allowing researchers to test novel drugs and treatments to prevent progression of this serious brain disorder.

DID YOU KNOW? CT scanning of the brain was invented in the early-Seventies

Picking apart the brain




© Alamy

The frontal lobes
The frontal lobes of the folded cerebral cortex take care of thought, reasoning, decisions and memories. This area is believed to be largely responsible for our individual personalities.

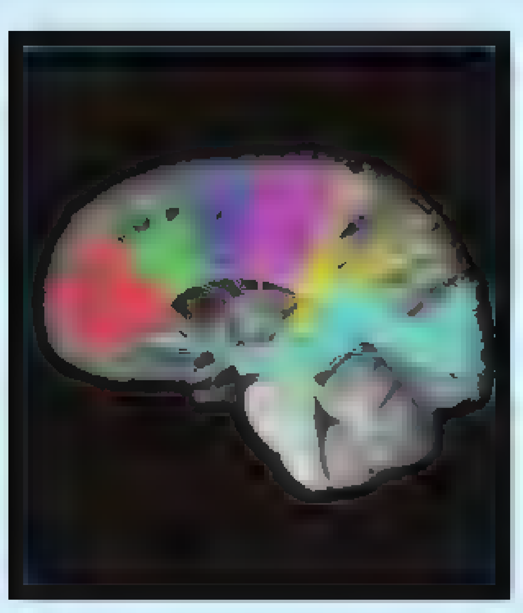
The sensory and motor cortexes
The pre- and post-central gyri receive the sensory information from the body and then dispatch orders to the muscles, in the form of signals through motor neurons.

The occipital cortex
In the posterior fossa of the skull, this cortex receives impulses from the optic nerves to form images. These images are in fact seen upside down, but this area enables them to be interpreted the right way up.

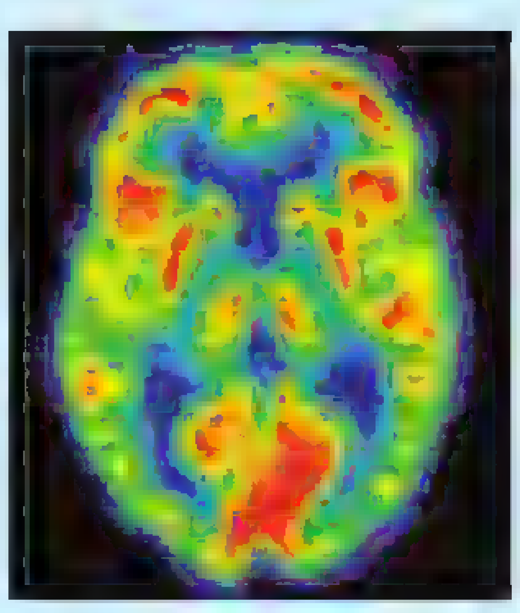
The brainstem
Formed from the midbrain, pons and medulla oblongata, the brainstem maintains the vital functions without us having to think about them. These include respiration and heart function; any damage to it leads to rapid death.

The cerebellum
The cerebellum is responsible for fine movements and co-ordination. Without it, we couldn't write, type, play musical instruments or perform any task that requires precise actions.

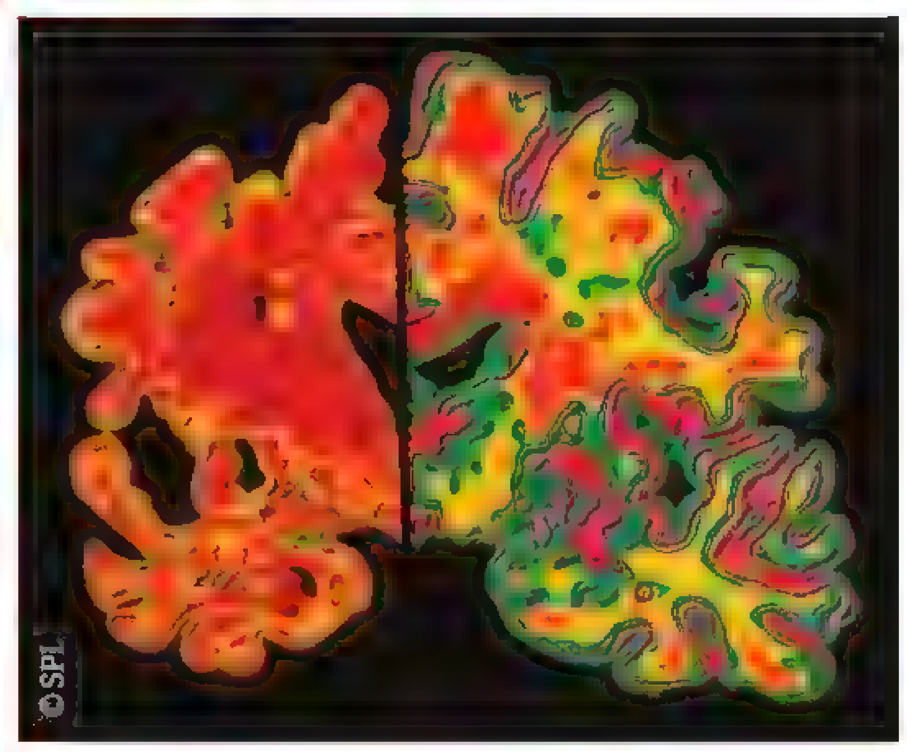
The pituitary gland
This tiny gland is responsible for hormone production throughout the body, which can thus indirectly affect our emotions and behaviours.



Diffusion tensor imaging (DTI)
This MRI variant relies on the direction of water diffusion within tissue. When a magnetic gradient is applied, the water aligns and, when the field is removed, the water diffuses according to a tissue's internal structure. This allows a 3D image of activity to be built up.



Positron emission tomography (PET)
This bleeding-edge technology detects gamma rays emitted from biologically active tissues based on glucose. It can pick up unusual biological activity, such as that from cancer. There have been recent advances to combine PET with CT or MRI to obtain lots of data quickly.


© SPL

Imaging Alzheimer's
Alzheimer's disease is a potentially debilitating condition, which can lead to severe dementia. The ability to diagnose it accurately and early on has driven the need for modern imaging techniques. The above image shows a PET scan. The right-hand side of the image (as you look at it) shows a normal brain, with a good volume and activity range. On the left-hand side is a patient affected by Alzheimer's. The brain is shrunken with fewer folds, and a lower range of activity – biologically speaking, there are far fewer neurons firing.

“Sleep is common to mammals, birds and reptiles and has been conserved through evolution”

The science of Sleep

Unravelling the mysteries behind insomnia, sleepwalking, dreams and more

We spend around a third of our lives sleeping; it is vital to our survival, but despite years of research, scientists still aren’t entirely sure why we do it. The urge to sleep is all-consuming, and if we are deprived of it, we will eventually slip into slumber even if the situation is life-threatening.

Sleep is common to mammals, birds and reptiles and has been conserved through evolution, even though it prevents us from performing tasks such as eating, reproducing and raising young. It is as important as food for keeping us alive; without it, rats will die within two or three weeks – the same amount of time it takes to die of starvation.

There have been many ideas and theories about why we sleep, from a way to rest after the day’s activities or a method for saving energy, to simply a way to fill time until we can be doing something useful, but all of these ideas are somewhat flawed. The body repairs itself just as well when we are sitting quietly, we only save around 100 calories a night by sleeping, and we wouldn’t need to catch up on sleep during the day if it were just to fill empty time at night.

One of the major problems with sleep deprivation is a resulting decline in cognitive ability; our brains just don’t work properly without sleep. We struggle with memory, learning,

5 TOP FACTS MOST COMMON DREAMS

Falling
1 One of the most common dreams is falling, but the danger is not as real as it seems. We often wake up before we hit the ground in our dreams, but if we don't we will come to no harm.

Flying
2 Some dreamers can take control of their dream experience, a phenomenon known as lucid dreaming. Once you realise you are dreaming you can start to enjoy strange new sensations like flying.

Taking exams
3 Adults often continue to dream about exams long after they have left school, and experience the same kinds of anxious feelings that they did when they were younger.

Being chased
4 The fight or flight response is hard-wired into our brains, and another common dream theme is being chased. The pursuer can be anything from a familiar face to a mythical monster.

Death
5 Dreams about the death of a loved one can be distressing, but there is absolutely no evidence to suggest humans are capable of predicting the future in their dreams.

DID YOU KNOW? *Marine mammals sleep with just half of their brain at a time, allowing them to surface for air*

Theories of why we sleep

Theory 1
Energy conservation
We save around 100 calories per night by sleeping; metabolic rate drops, the digestive system is less active, heart and breathing rates slow, and body temperature drops. However, the calorie saving equates to just one cup of milk, which from an evolutionary perspective does not seem worth the accompanying vulnerability.

Theory 3
Restoration
One of the major problems with sleep deprivation is a decrease in cognitive function, accompanied by a drop in mood, and there is mounting evidence that sleep is involved in restoring the brain. However, there is little evidence to suggest that the body undergoes more repair during sleep compared to rest or relaxation.

Theory 2
Evolutionary protection
An early idea about the purpose of sleep is that it is a protective adaptation to fill time. For example, prey animals with night vision might sleep during the day to avoid being spotted by predators. However, this theory cannot explain why sleep-deprived people fall asleep in the middle of the day.

Theory 4
Memory consolidation
One of the strongest theories regarding sleep is that it helps with consolidation of memory. The brain is bombarded with more information during the day than it is possible to remember, so sleep is used to sort through this information and selectively practice parts that need to be stored.

planning and reasoning. A lack of sleep can have severe effects on our performance, ranging from irritability and low mood, through to an increased risk of heart disease and a higher incidence of road traffic accidents.

Sleep can be divided into two broad stages, non-rapid eye movement (NREM), and rapid eye movement (REM) sleep. The vast majority of our sleep (around 75 to 80 per cent) is NREM, characterised by electrical patterns in the brain known as 'sleep spindles' and high, slow delta waves. This is the time we sleep the deepest.

Without NREM sleep, our ability to form declarative memories, such as learning to associate pairs of words, can be seriously impaired; deep sleep is important for transferring short-term memories into long-term storage. Deep sleep is also the time of peak growth hormone release in the body, which is important for cell reproduction and repair.

The purpose of REM sleep is unclear; the effects of REM sleep deprivation are less severe than NREM deprivation, and for the first two weeks humans report little in the way of ill effects.

REM sleep is the period during the night when we have our most vivid dreams, but people dream during both NREM and REM sleep. During NREM sleep, dreams tend to be more concept-based, whereas during REM sleep dreams are more vivid and emotional.

Some scientists argue that REM sleep allows our brains a safe place to practice dealing with situations or emotions that we might not encounter during our daily lives; during REM sleep our muscles are temporarily paralysed, preventing us acting out these emotions. Others think that it might be a way to unlearn memories, or to process unwanted feelings or emotions. Each of these ideas has its flaws, and no one knows the real answer.

Over the next few pages we will delve into the science of sleep and attempt to make sense of the mysteries of the sleeping brain. ▶

"As you progress through stage-three sleep, you become much more difficult to wake up"

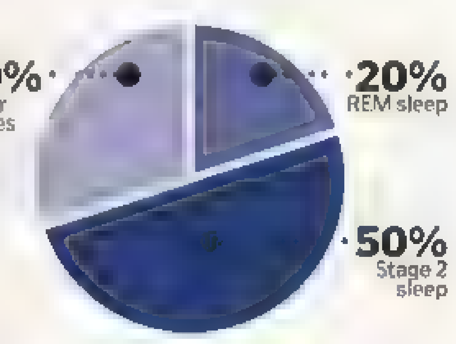
The sleep cycle

During the night, you cycle through five separate stages of sleep every 90 to 110 minutes

The five stages of sleep can be distinguished by changes in the electrical activity in your brain, measured by electroencephalogram (EEG). The first stage begins with drowsiness as you drift in and out of consciousness, and is followed by light sleep and then by two stages of deep sleep. Your brain activity starts to slow down, your breathing, heart rate and temperature drop, and you become progressively more difficult to wake up. Finally, your brain perks up again, resuming activity that looks much more like wakefulness, and you enter rapid eye movement (REM) sleep; the time that your most vivid dreams occur. This cycle happens several times throughout the night, and each time, the period of REM sleep grows longer. ▶

Growth hormone release
After you fall asleep, the pituitary gland ramps up its production of growth hormone.

How much time do you spend in each sleep stage?



Low temperature
Body temperature falls just before sleep, and is maintained at a lower level throughout the night.

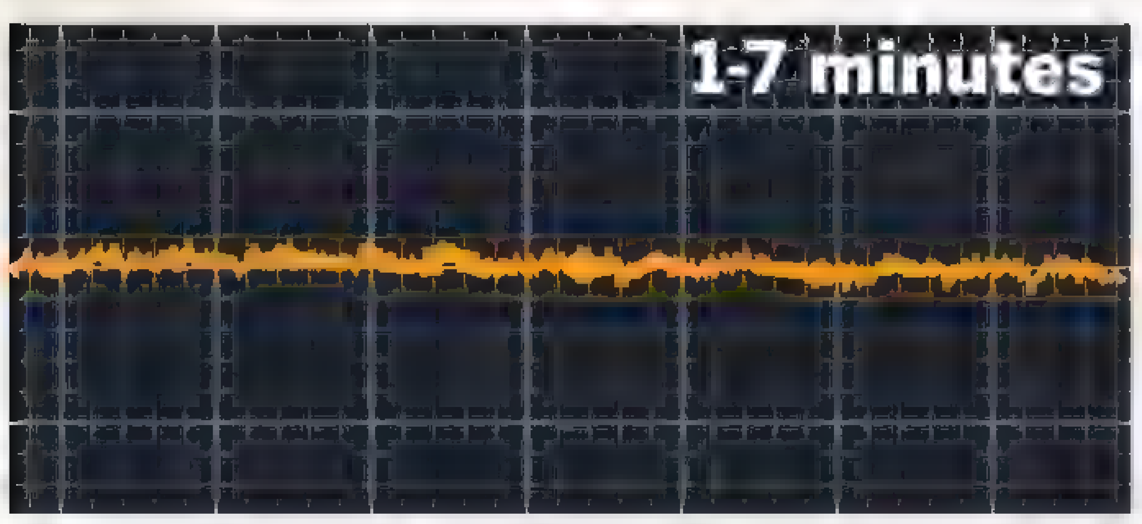
Limited movement
Muscle tone drops during sleep, but you still change position, tossing and turning.

Different when dreaming
During REM sleep, your heart rate rises, but your larger muscles are paralysed; just your fingers, toes and eyes twitch as you dream.

Slow breathing
As you fall into deeper and deeper sleep, your breathing becomes slower and more rhythmic and your heart rate drops.

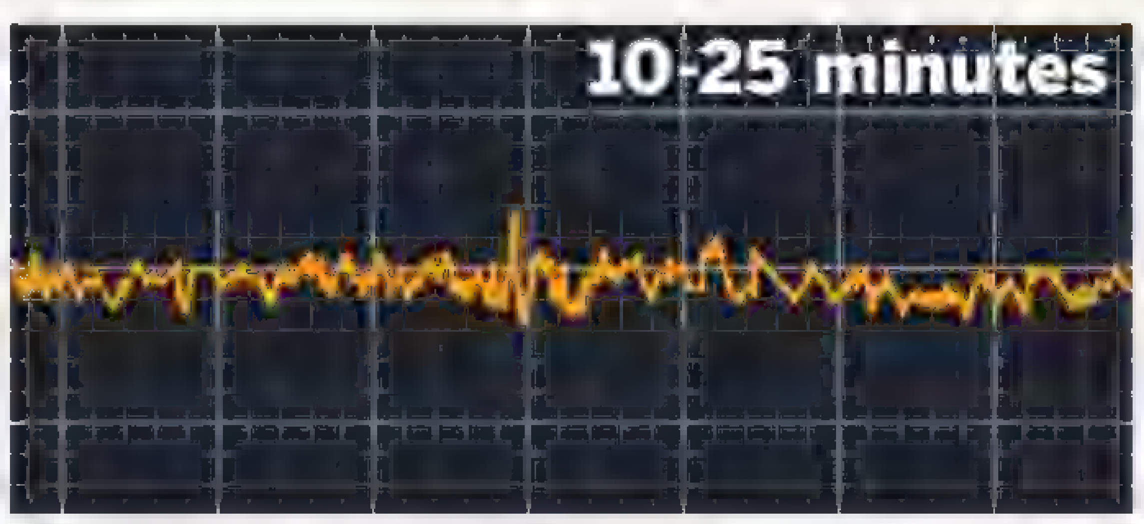
Stages of sleep

Not all sleep is the same; there are five separate stages, divided up by brain activity



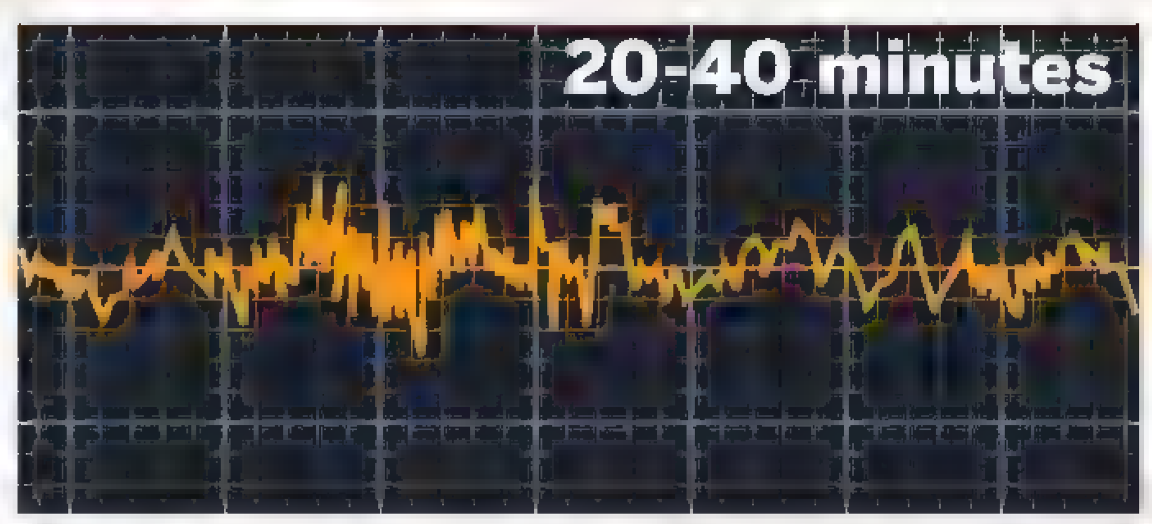
1 Drowsiness

During the first stage of sleep you are just drifting off; your eyelids are heavy and your head starts to drop. During this drowsy period, you are easily awoken and your brain is still quite active. The electrical activity on an electroencephalogram (EEG) monitor starts to slow down, and the cortical waves become taller and spikier. As the sleep cycle repeats during the night, you re-enter this drowsy half-awake, half-asleep stage.



2 Light sleep

After a few minutes, your brain activity slows further, and you descend into light sleep. On the EEG monitor, this stage is characterised by further slowing in the waves with an increase in their size, and short one or two-second bursts of activity known as 'sleep spindles'. By the time you are in the second phase of sleep, your eyes stop moving, but you can still be woken quite easily.



3 Moderate sleep

As you start to enter this stage, your sleep spindles stop, showing that your brain has entered moderate sleep. This is then followed by deep sleep. The trace on the EEG slows still further as your brain produces delta waves with occasional spikes of smaller faster waves in between. As you progress through stage-three sleep, you become much more difficult to wake up.

HEAD 2 HEAD
SLEEPLESS IN...

1. SLEEPY

Tokyo, Japan
According to data collected by the Jawbone UP fitness tracker in 2014, Tokyo is the city that sleeps the least, averaging just five hours and 44 minutes each night.

2. SLEEPIER

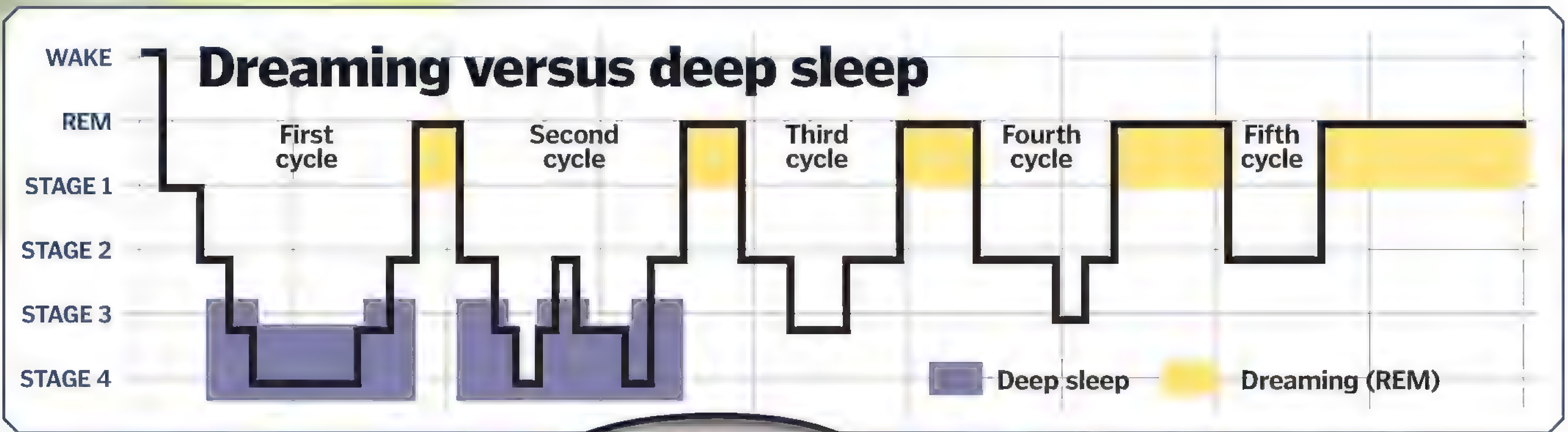
Moscow, Russia
People living in the famous Russian capital sleep in late, rising at 8:08am on average after six hours and 42 minutes of sleep.

3. SLEEPIEST

Melbourne, Australia
The residents of the Australian city of Melbourne clock an average of six hours and 58 minutes of sleep every night.

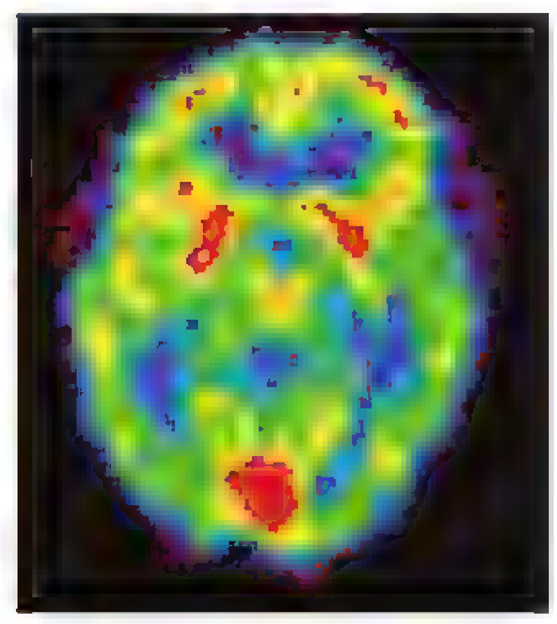
DID YOU KNOW? *Sleeping in at the weekends causes 'social jet lag' and makes it more difficult to get up on Monday morning*

Dreaming versus deep sleep

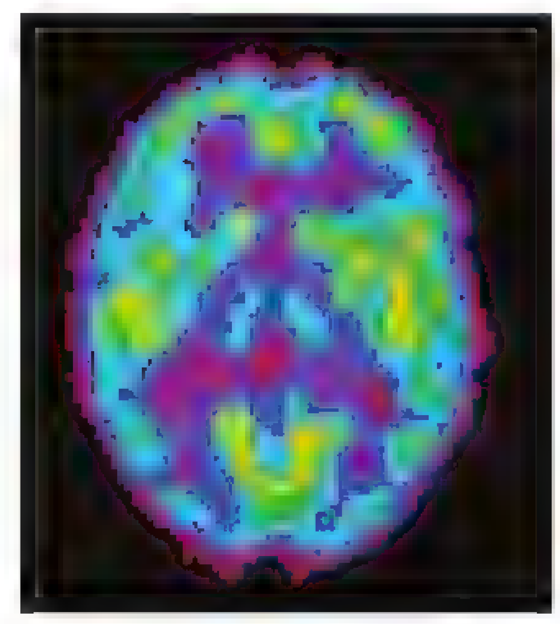


Clearing the mind

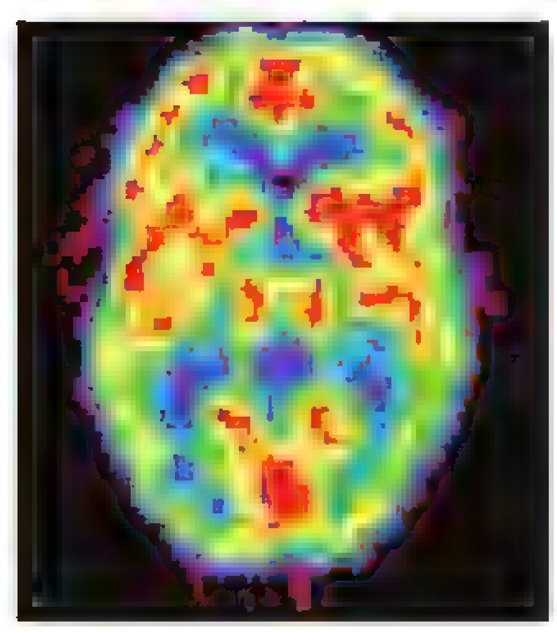
Brain activity



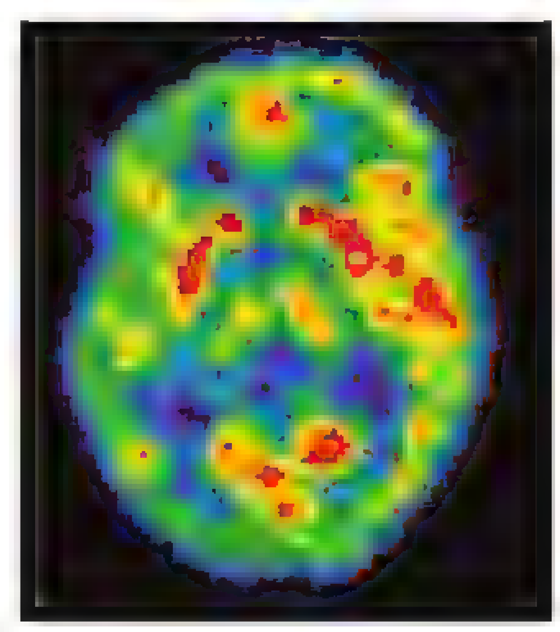
Wide awake
The red areas in this scan show areas of activity in the waking human brain, while the blue areas represent areas of inactivity.



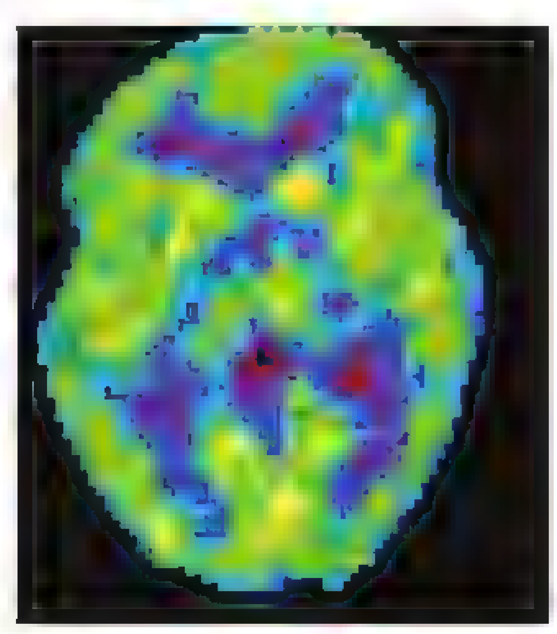
Deep sleep
During the later stages of NREM sleep, the brain is less active, shown here by the cool blue and purple colours that dominate the scan.



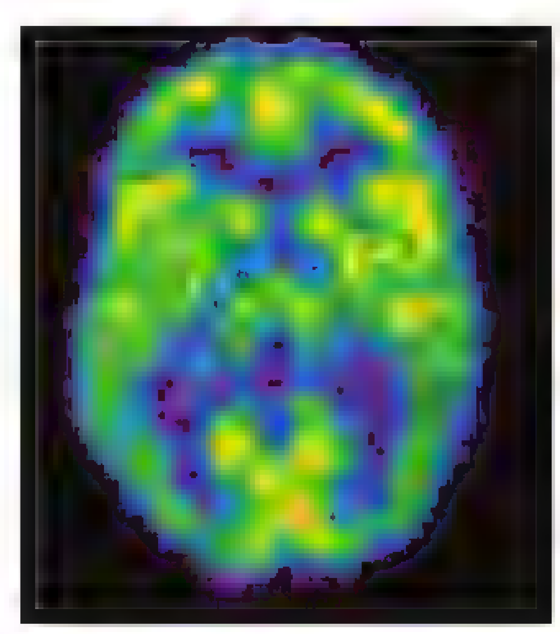
REM (dream) sleep
When the brain is dreaming it is very active, showing similar red patterns of activity to the waking brain.



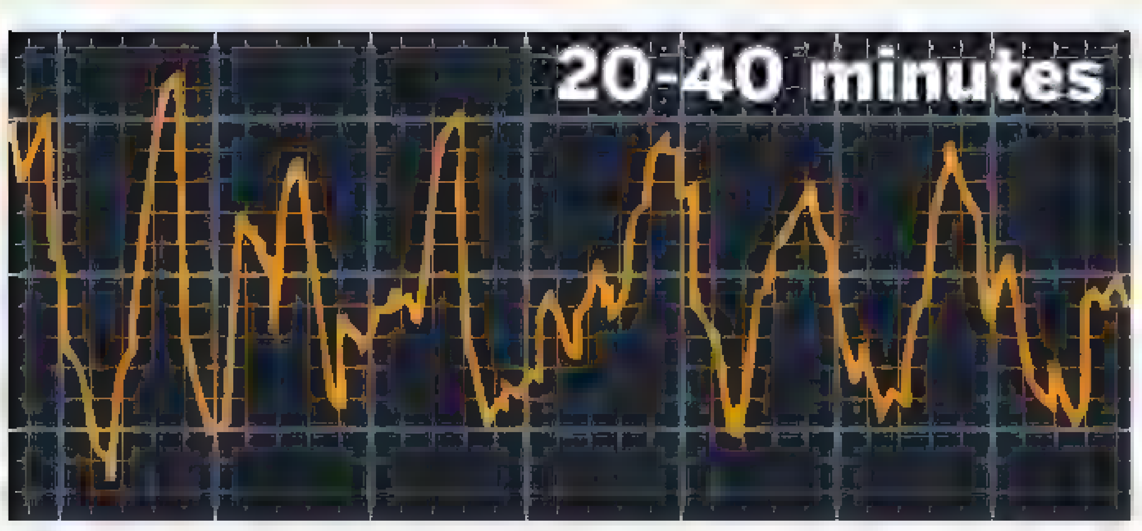
Light sleep
The first stages of NREM sleep, the brain is less active than when awake, but you remain alert and easy to wake up.



Sleep deprivation
The sleep-deprived brain looks similar to the brain during NREM sleep, showing patterns of inactivity.

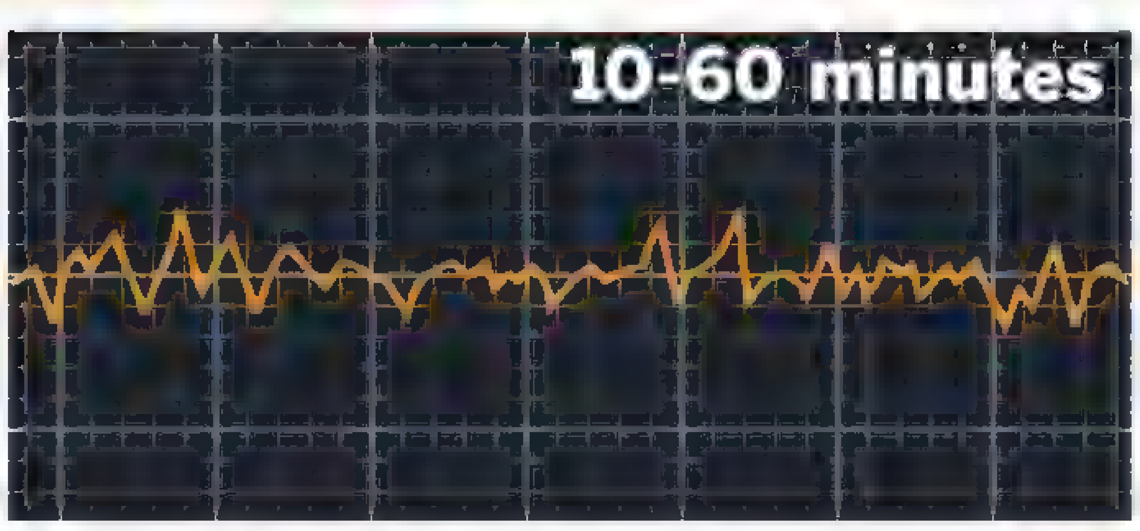


NREM sleep
As you descend through the four stages of NREM sleep, your brain becomes progressively less active.



4 Deep sleep

There is some debate as to whether sleep stages three and four are really separate, or whether they are part of the same phase of sleep. Stage four is the deepest stage, and during this time, you are extremely hard to wake. The EEG shows tall, slow waves known as delta waves, your muscles relax and your breathing becomes slow and rhythmic, which can lead to snoring.



5 REM sleep

After deep sleep, your brain starts to perk up and its electrical activity starts to resemble the waking brain. This is the period of the night when most dreams happen. Your muscles are temporarily paralysed, and your eyes dart back and forth, giving this stage its name, rapid eye movement (REM) sleep. You cycle through the stages of sleep about every 90 minutes, experiencing between three and five dream periods each night.

"Difficulty falling asleep is known as insomnia, and is one of the most familiar sleep disorders"

Sleep disorders

There are over 100 different disorders that can get in the way of a good night's sleep

Sleep is necessary for our health, so disruptions to the quality or quantity of our sleep can have a serious negative impact on daily life, affecting both physical health and mental wellbeing.

Sleep disorders fall into four main categories: difficulty falling asleep, difficulty staying awake, trouble sticking to a regular sleep pattern and abnormal sleep behaviours.

Struggling with falling asleep or staying asleep is known as insomnia, and is one of the most familiar sleep disorders; around a third of the population will experience it during their lifetime.

Difficulty staying awake, or hypersomnia, is less common. The best-known example is narcolepsy; sufferers experience excessive daytime sleepiness, accompanied by uncontrollable short sleeps during the day.

Trouble sticking to a regular sleeping pattern can either be caused by external disruption to normal day-to-day rhythms, for example by jet lag or shift work. It can also be the result of an internal problem with the part of the brain responsible for setting the body clock.

Abnormal sleep behaviours include problems like night terrors, sleepwalking and REM-sleep behaviour disorder. Night terrors and sleepwalking most commonly affect children, and tend to resolve themselves with age, but other sleep behaviours persist into adulthood; in REM-sleep behaviour disorder, the normal muscle paralysis that accompanies dreaming fails, and people begin to act out their dreams.

Treatment for different sleep disorders varies depending on the particular problem, and can be as simple as making the bedroom environment more conducive to restful sleep. ▶

A continuous positive airway pressure (CPAP) machine pumps air into a close-fitting mask, preventing the airway from collapsing

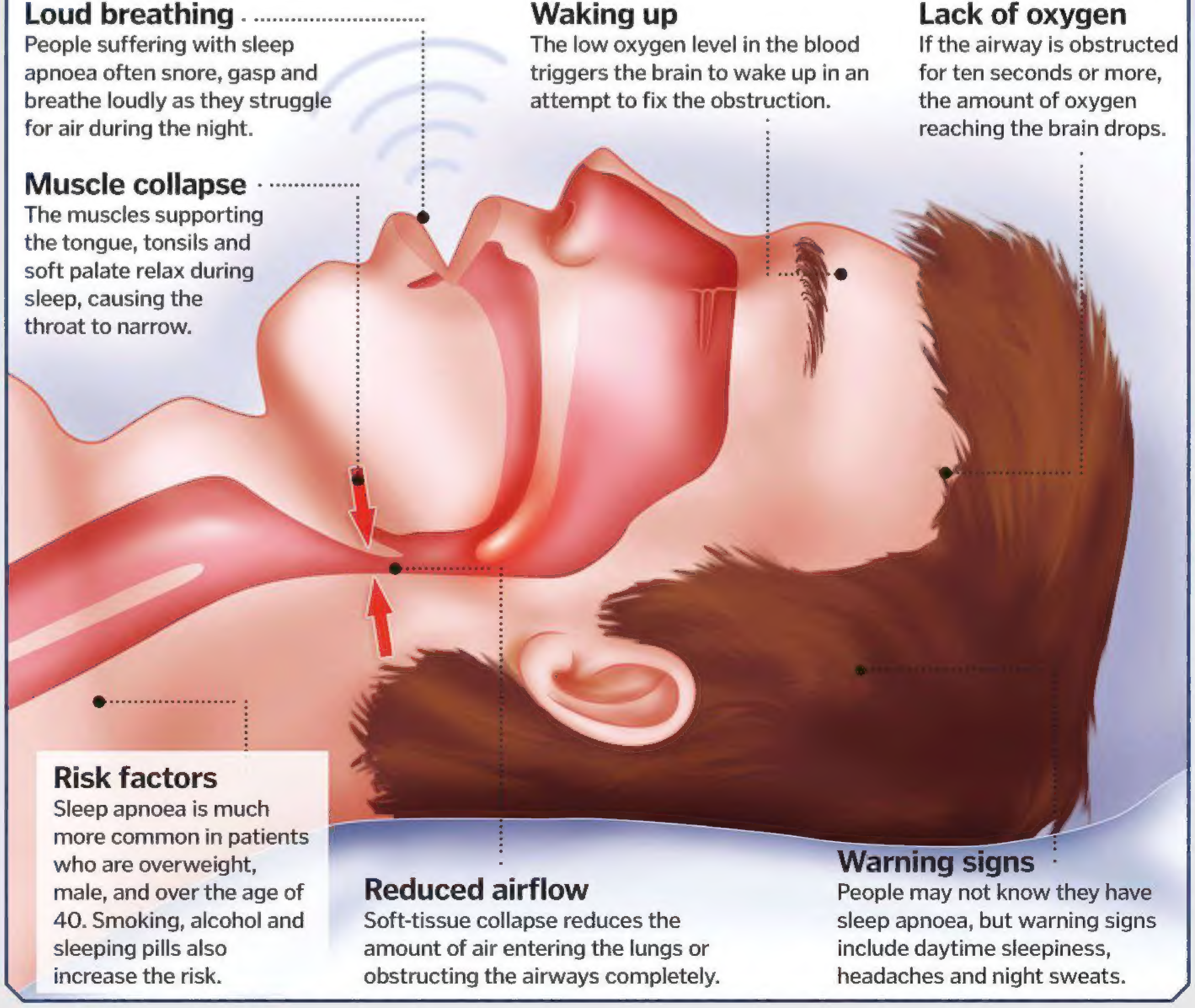
Sleepwalking

Sleepwalking affects between one and 15 per cent of the population, and is much more common in children than in adults, tending to happen less and less after the age of 11 or 12. Sleepwalkers might just sit up in their bed, but can perform complex behaviours, such as walking, getting dressed, cooking, or even driving a car. Although sleepwalkers seem to be acting out their dreams, sleepwalking tends to occur during the deep-sleep phase of NREM sleep and not during REM sleep.

Sleepwalkers can perform complicated actions while in deep NREM sleep

Sleep apnoea

Sleep apnoea is a dangerous sleep disorder; the walls of the airways relax so much during the night that breathing is interrupted for ten seconds or more, restricting the supply of oxygen to the brain. This lack of oxygen initiates a protective response, pulling the sufferer out of deep sleep to protect them from damage. Sometimes this causes people to wake up, but often it will just put them into a different sleep stage, interrupting their rest and causing feelings of tiredness the next day.



20 hours a day

SLEEPIEST ANIMAL

The little brown bat is the sleepiest animal on the planet, spending a massive 20 hours every day snoozing. The koala is a close rival, sleeping for over 14 hours every day.

DID YOU KNOW? *After 24 hours without sleep your cognition is at the same level as a person with a blood alcohol content of 0.10%*

Narcolepsy

Narcolepsy is a chronic condition that causes people to suddenly fall asleep during the daytime. In the United States, it affects one in every 3,000 people. Narcoleptics report excessive daytime sleepiness, accompanied by a lack of energy and impaired ability to concentrate. They fall asleep involuntarily for periods lasting just a few seconds at a time, and some can continue to perform tasks such as writing, walking, or even driving during these microsleeps. In 70 per cent of cases, narcolepsy is accompanied by cataplexy, where the muscles go limp and become difficult to control. It has been linked to low levels of the neurotransmitter hypocretin, which is responsible for promoting wakefulness in the brain.


People with narcolepsy fall asleep involuntarily during the day

Insomnia

Insomniacs have difficulty falling asleep or staying asleep. Sufferers can wake up during the night, wake up unusually early in the morning, and report feeling tired and drained during the day. Stress is thought to be one of the major causes of this sleep disruption, but it is also associated with mental health problems like depression, anxiety and psychosis, and with underlying medical conditions ranging from lung problems to hormone imbalances. After underlying causes have been ruled out, management of insomnia generally involves improving 'sleep hygiene' by sticking to regular sleep patterns, avoiding caffeine in the evening, and keeping the bedroom free from light and noise at night.


One in three people in the UK will experience insomnia in their lifetime

Sleep studies

The most common type of sleep study is a polysomnogram (PSG); an overnight test performed in a specialist sleep facility. Electrodes are placed on the chin, scalp and eyelids to monitor brain activity and eye movement, and pads are placed on the chest to track heart rate and breathing. Blood pressure is also monitored throughout the night, and the amount of oxygen in the bloodstream can be tracked using a device worn on the finger. The equipment allows specialists to monitor how long it takes a patient to fall asleep, and then to follow their brains and bodies as they move through each of the five sleep stages.


Electrodes monitor brain activity, eye movement, heart rate and breathing in sleep studies

How to get a good night's sleep

Understanding your biological clock is the key to a healthy night's sleep

Your body is driven by an internal circadian master clock known as the suprachiasmatic nucleus, which is set on a time scale of roughly 24 hours. This biological clock is set by sunlight; blue light hits special receptors in your eyes, which feed back to the master clock and on to the pineal gland. This suppresses the production of the sleep hormone melatonin and tells your brain that it is time to wake up.

Disruptions in light exposure can play havoc with your sleep, so it is important to ensure that your bedroom is as dark as possible. Many electronic devices produce enough light to reset your biological clock, and using backlit screens late at night can confuse your brain, preventing the production of melatonin and delaying your sleep.

Ensuring you see sunlight in the morning can help to keep your circadian clock in line, and sticking to a regular sleep schedule, even at the weekends, helps to keep this rhythm regular.

Another important factor in a good night's sleep is winding down before bed. Stimulants like caffeine and nicotine keep your brain alert and can seriously disrupt your sleep, and even depressants like alcohol can have a negative effect; even though it calms the brain, it interferes with normal sleep cycles, preventing proper deep and REM sleep.

The blue light from televisions, mobile phones and computer screens disrupts your circadian rhythm

THE DANGERS OF SLEEP DEPRIVATION

Lack of sleep doesn't just make you tired; it can have dangerous unseen effects

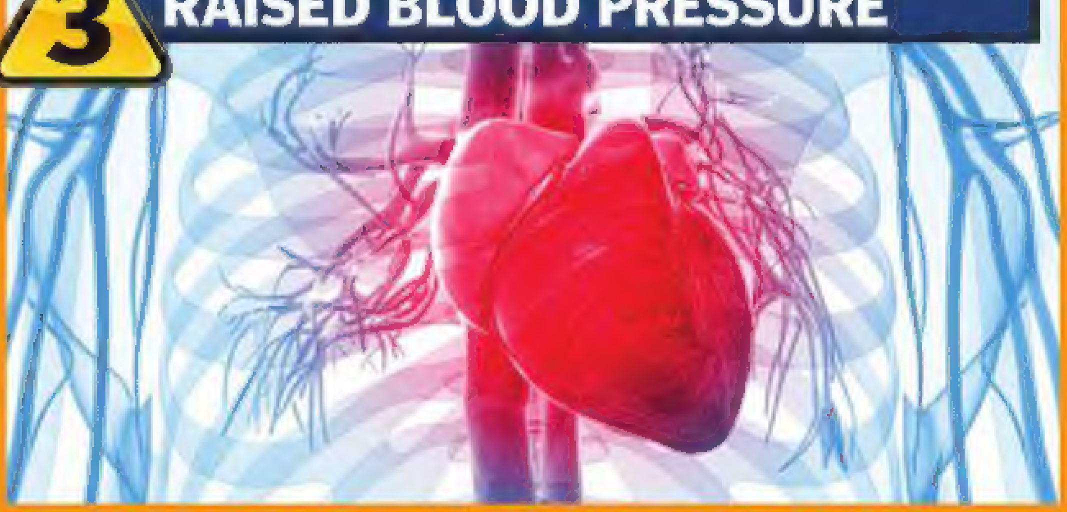
1 IMPAIRED JUDGEMENT

Sleep deprivation impacts your visual working memory, making it difficult to tell the difference between relevant and irrelevant stimuli in your environment, and affects your emotional intelligence, behaviour and ability to manage stress.

2 WEIGHT GAIN

Sleep deprivation affects the levels of hormones involved in regulating appetite. Levels of leptin (the hormone that tells you how much stored fat you have) drop, and levels of the hunger hormone ghrelin rise.

3 RAISED BLOOD PRESSURE



Poor sleep can raise blood pressure, and in the long term is associated with an increased risk of diseases such as coronary heart disease and stroke. This danger is increased in people with sleep apnoea.

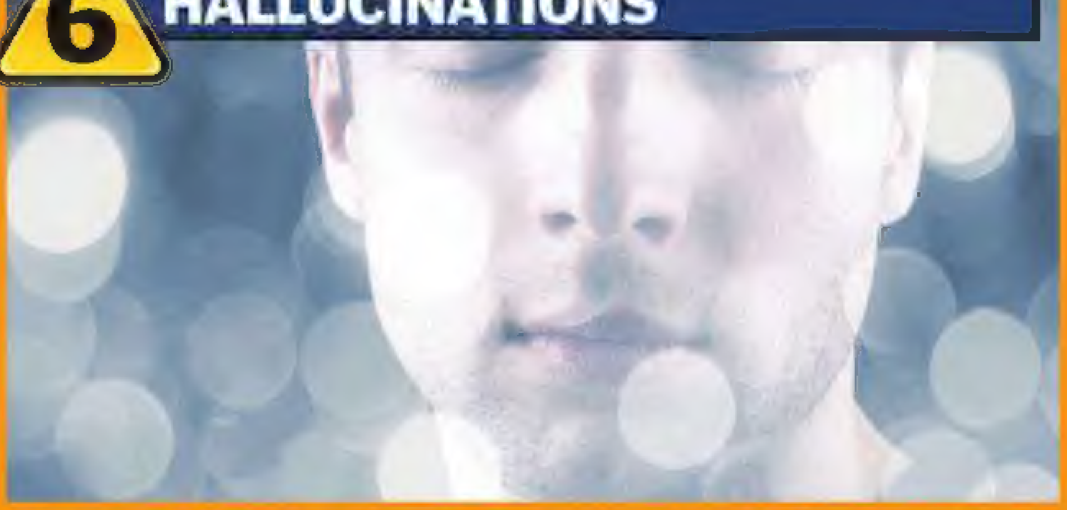
4 INCREASED ACCIDENTS

In the USA it is estimated that 100,000 road accidents each year are the result of driver fatigue, and over a third of drivers have admitted to falling asleep at the wheel.

5 MOOD DISORDERS

Mental health problems are linked to sleep disorders, and sleep deprivation can play havoc with neurotransmitters in the brain, mimicking the symptoms of depression, anxiety and mania.

6 HALLUCINATIONS



Severe sleep deprivation can lead to hallucinations; seeing things that aren't really there. In rare cases can lead to temporary psychosis or symptoms that resemble paranoid schizophrenia.

STRANGE BUT TRUE
STAYING AWAKE

Who holds the world record for the longest time without sleep?

A Randy Gardner B Barack Obama C No one

Answer:
Randy Gardner used to hold the official world record, set at 264 hours (11 days) in 1964, but today no one is able to claim the title. The Guinness Book of World Records scrapped it in 1989 because trying to break the record is considered too dangerous.

DID YOU KNOW? *Sleep deprivation was found to have played a significant role in the nuclear meltdown at Chernobyl in 1986*

Sleep myths debunked

We explain the science behind five of the most common myths about sleep

"COUNTING SHEEP HELPS YOU SLEEP"

This myth was put to the test by the University of Oxford, who challenged insomniacs to either count sheep, imagine a relaxing scene, or do nothing as they tried to fall asleep. When they imagined a relaxing scene, the participants fell asleep an average of 20 minutes earlier than when they tried either of the other two methods.

MYTH DEBUNKED

"YAWNING WAKES YOU UP"

MYTH DEBUNKED

Yawning has long been associated with tiredness and was fabled to provide more oxygen to a sleepy brain, but this is not the case. New research suggests that we actually yawn to cool our brains down, using a deep intake of breath to keep the brain running at its optimal temperature.

"TEENAGERS ARE LAZY"

MYTH DEBUNKED

Sleep habits start to change just before puberty, and between the ages of ten and 25, people need around nine hours of sleep every night. Teens can also experience a shift in their circadian rhythm, called sleep phase delay, pushing back their natural bedtime by around two hours, and encouraging them to sleep in.

"YOU SHOULD NEVER WAKE A SLEEPWALKER"

Many people have heard that waking a sleepwalker might kill them, but there is little truth behind these tales. Waking a sleepwalker can leave them confused and disorientated, but the act of sleepwalking in itself can be much more dangerous; gently guiding a sleepwalker back to their bed is the safest option, but waking them carefully shouldn't do any harm.

MYTH DEBUNKED

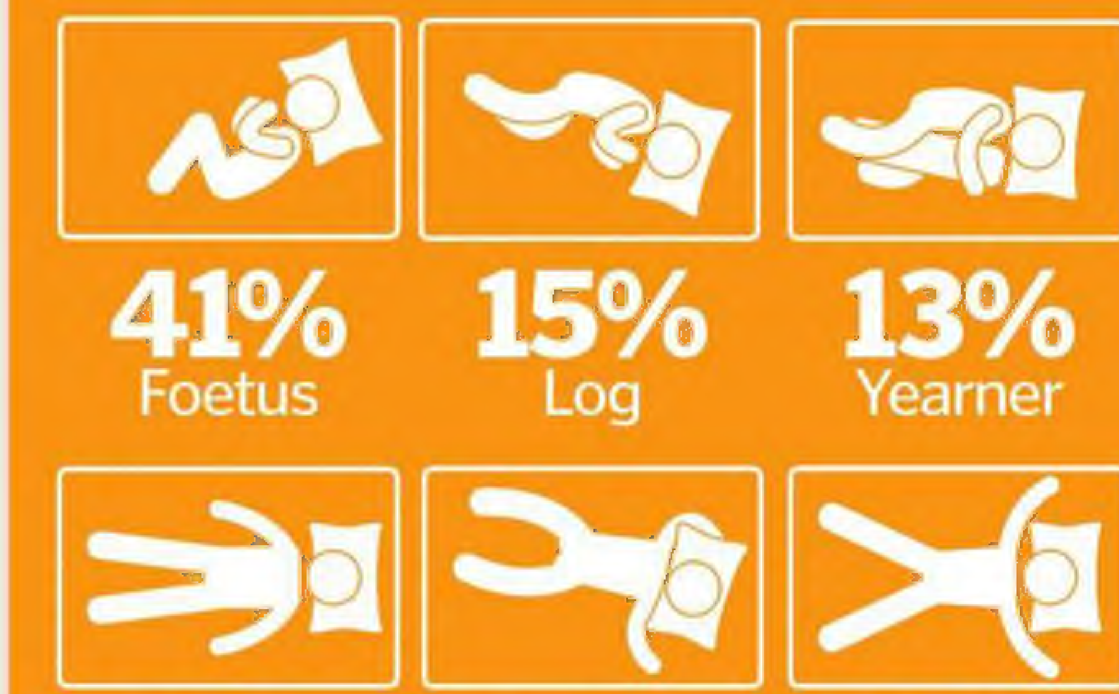
"CHEESE GIVES YOU NIGHTMARES"

MYTH DEBUNKED

The British Cheese Board conducted a study in an attempt to debunk this myth by feeding 20g (0.7oz) of cheese to 200 volunteers every night for a week and asking them to record their dreams. There were no nightmares, but strangely 75 per cent of men and 85 per cent of the women who ate Stilton reported vivid dreams.

SLEEP STATS

What are the most common sleeping positions?



41% Foetus
15% Log
13% Yearner
8% Soldier
7% Freefaller
5% Starfish

How does sleep time vary with age?

What keeps the UK up at night?

67% Discomfort
36% Noise
13% Partner
34% Temperature
19% Light

Which country sleeps the longest?

What do people dream about?